Splitting the Hand in the Functional Position After Brain Impairment: A Randomized, Controlled Trial

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ABSTRACT. Lannin NA, Horsley SA, Herbert R, McCluskey A, Cusick A. Splinting the hand in the functional position after brain impairment: a randomized, controlled trial. Arch Phys Med Rehabil 2003;84:297-302.

Objective: To evaluate the effects of 4 weeks of hand splinting on the length of finger and wrist flexor muscles, hand function, and pain in people with acquired brain impairment.

Design: Randomized, assessor-blinded trial.

Setting: Rehabilitation center in Australia.

Participants: Twenty-eight adults with acquired brain impairment, all within 6 months of the first injury. There was 1 withdrawal.

Interventions: Subjects in both experimental (n=17) and control (n=11) groups participated in routine therapy—motor training for upper-limb use and upper-limb stretches—5 days a week. The experimental group also wore an immobilizing hand splint in the functional position (10°–30° wrist extension) for a maximum of 12 hours each night for the duration of the 4-week intervention period.

Main Outcome Measures: The length of the wrist and extrinsic finger flexor muscles was evaluated by measuring the torque-controlled range of wrist extension with the fingers extended. Functional hand use was evaluated with the Motor Assessment Scale. Pain was evaluated with a visual analog scale.

Results: The effects of splinting were statistically nonsignificant and clinically unimportant. At follow-up, estimates of treatment effects slightly favored the control group: range of motion at the wrist favored controls by 2° (95% confidence interval [CI], −7.2° to 3.2°), function favored controls by 0.2 points (95% CI, −2.7 to 2.3), and pain favored the experimental group by 1cm (95% CI, −4.6 to 2.2).

Conclusions: An overnight splint-wearing regimen with the affected hand in the functional position does not produce clinically beneficial effects in adults with acquired brain impairment.

Key Words: Contracture; Hemiplegia; Occupational therapy; Rehabilitation; Spasticity.

PEOPLE WITH acquired brain impairment, such as stroke or traumatic brain injury (TBI), commonly experience loss of movement and strength in the upper limb.[1,2] Subsequently, secondary complications, such as contracture, often occur.[2-4] Contracture, or loss of joint range of motion (ROM), may be due to changes in the passive mechanical properties of muscles (perhaps consequent to a reduction in serial sarcomere numbers)[5] or may be associated with spasticity.[2,6] Contracture is common after both stroke and TBI.[4,5] Contractures are associated with poor functional recovery[3,7] because they restrict ROM and interfere with the performance of many everyday tasks.[8] Pain is also widely reported to be a secondary complication of acquired brain impairment.[9-11]

In some clinics, patients who experience a loss of movement after acquired brain impairment are routinely[12] provided with hand splints.[12-16] There are discrepancies in splinting practices, and the use of hand splints with this population is controversial.[9,16,17] The aims of splinting include reductions in spasticity[9,12,15,16,18] and pain[9,16,18]; improvement of function[9,18]; compensation for protective sensation[16]; and prevention of contracture,[9,12,16,18] deformity,[9,16] overstretching,[16,18] and edema.[9,12,16] Of these, the most common aim,[12] and the one used as a basis for our study, is the prevention of contracture. Despite the variety of aims, there are only 2 basic theoretical rationales for splinting in this population. These are the biomechanical[9,16,18,19] and the neurophysiologic[9,16,18,20] rationales. Therapists who apply the biomechanical rationale recommend splinting to prevent length-associated changes in muscles and connective tissue. Therapists who apply the neurophysiologic rationale recommend splinting to inhibit reflexive contraction of muscle.

Regardless of the rationale used, few therapists use splints on patients who have active movement.[18] Typically, therapists recommend a static (resting) splint for patients without active movement. This splint positions the wrist and fingers in the functional position.[12] A major controversy arising from the neurophysiologic rationale is whether to place this splint on the palmar or dorsal surface of the hand. The controversy is due to the belief that a splint placed on the palmar surface of the hand will stimulate the flexor muscles and therefore increase spasticity.[18,21,22] The research literature to date does not, however, resolve this or other controversies.

The efficacy of splinting after acquired brain impairment is yet to be established.[7,9,12,17] Most published studies[21-25] have not used true experimental designs,[17,24] and most have measured the effect of splinting on spasticity. The clinical relevance of spasticity as an outcome is questionable because recent research suggests that spasticity is unrelated, or only weakly related, to functional ability after stroke.[2,5] The efficacy of splinting, therefore, needs to be addressed by using randomized, controlled trials (RCTs) that investigate the effect on clinically relevant variables, such as joint ROM, hand function, and pain.

The primary aim of this study was to determine the effect of 4 weeks of splint wearing on the length of the wrist and finger flexor muscles in patients who were in the early stages of

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Supported by donation of splinting material only, by Smith+Nephew Rehabilitation, Sydney, Australia.

No commercial party having a direct financial interest in the results of the research supporting this article has or will confer a benefit upon the author(s) or upon any organization with which the author(s) is/are associated.

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0003-9993/03/8402-7562$35.00/0

doi:10.1053/apmr.2003.50031

rehabilitation after acquired brain impairment. Secondary aims were to determine whether splint wearing affected the recovery of hand function and pain in the upper limb.

METHODS

Participants

The trial included 28 subjects who were recruited on their admission to the Townsville Hospital Rehabilitation Unit, Queensland, Australia. Subjects were required to meet the following criteria for inclusion in the study: (1) have a history of a single stroke or brain injury resulting in upper-limb hemiplegia of no more than 6 months in duration, (2) be unable to actively extend the affected wrist, and (3) be between 18 and 80 years old. Subjects were excluded if they had language comprehension, perceptual, or cognitive deficits that would prevent written, informed consent or participation in the program. Because it is not customary in clinical practice to provide a hand splint to patients with active movement, subjects with active wrist extension were excluded from participating in the study. Of 53 consecutive patients admitted to the unit with acquired brain impairment, 23 patients were excluded because they did not meet the inclusion criteria. Reasons for exclusion included active wrist extension (n=19), concurrent fracture of the hemiplegic arm (n=2), and decreased ability to provide informed consent (n=2). Two patients who were eligible elected not to participate in the study. The protocol was approved by hospital and university ethics committees.

Sample Size

The required sample size was determined by using the pooled estimate of within-group standard deviations (SDs) obtained from pilot data.[26] A 5° change in measured muscle extensibility was selected as the smallest clinical change that would be considered worthwhile after the extensive period of splint wearing. Power calculations indicated that a sample of 28 subjects would provide an 80% probability of detecting a 5° effect on wrist and finger flexor length, with noncompliance of 20%, loss to follow-up of 10%, and α set at .05.

Design

An assessor-blinded, randomized design was used. A random number table was used to generate the random number sequence. Subjects were randomly allocated to control and experimental groups by using a simple randomization process.[26] Random allocation occurred after baseline measurement.[27] The investigator contacted an independent person to obtain group allocation for each subject. This ensured concealed randomization. Both groups received routine therapy. In addition, the experimental group wore a hand splint for up to 12 hours a night for 4 weeks.

Intervention

Subjects in both groups participated in routine therapy for individual motor training and upper-limb stretches 4 days a week. This routine therapy was provided as follows.

Upper-limb motor training. An individually designed motor training program[8,10,28] aimed at improving performance in upper-limb tasks was conducted with each subject for approximately 30 minutes a day, 5 days a week.

Stretching. Two 30-minute stretches were applied to the subject's upper limbs 5 days a week for the duration of the study and follow-up period (5wk in total). These stretches provided a prolonged low-load stretch to muscles at risk of developing contracture.[1,3] The upper-limb stretches used in the study included the following: first, a seated weight-bearing stretch of the upper limb with (1) the shoulder joint positioned in external rotation, abduction, and slight extension; (2) the elbow in extension; (3) the forearm in supination; and (4) the wrist and fingers in extension. Second, a seated stretch of the upper limb involving use of an inflatable long-arm air splint[a] with (1) the shoulder joint positioned in external rotation and abduction, (2) the elbow positioned in extension, (3) the wrist positioned in extension, and (4) the thumb positioned in abduction.

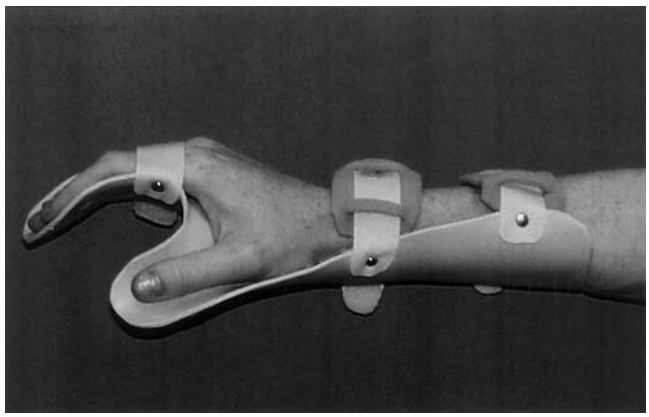

Fig 1. Palmar mitt splint (wrist positioned at 10°–30° extension; opposition and abduction of the thumb; semiflexion of the finger joints) worn by the experimental group overnight for up to 12 hours a day, 7 days a week.

In addition to the routine motor training and stretching described previously, subjects in the experimental group wore a static, palmar resting mitt splint on a daily basis, for a maximum of 12 hours each night, for the duration of the 4-week intervention period. The splint was worn at night partly to keep treating physiotherapists blinded to subject allocation. One of the investigators (NAL) and the nursing staff on the hospital ward were responsible for ensuring that the splints were applied and fitted correctly for the duration of the study. The splint held the hand in the functional resting position: wrist positioned between 10° and 30° extension, thumb in opposition and abduction, and semiflexion of the finger joints (fig 1).[9,13,29] No adjustments to the splints were required during the study period to maintain the functional resting position.

Measurement Procedures

Outcome measures were obtained on 3 occasions: before random allocation (baseline), at the end of the 4-week experimental period on the 30th day (postintervention), and 1 week after the experimental intervention was ceased on the 38th day (follow-up). Measurements on day 30 were taken at least 3 hours after the splint had been removed. Measurements were conducted by one of the investigators (SAH), who was assisted by a second clinical physiotherapist. Both assessors were blinded to allocation.

Outcome Measures

Three outcomes were recorded. These were length of wrist and finger flexor muscles, hand and arm function, and pain levels.

The length of the wrist and finger flexor muscles was obtained by using a standard procedure,[30] which provided a torque-controlled measurement of wrist extension with the fingers extended. Good reliability of this procedure has been

established, and it has been shown to be sensitive within 5°.[30] Using a spring balance, the assessor applies a known torque to the wrist to produce passive wrist extension. Wrist angle is then measured with skin-surface markers and a goniometer, which is attached to the instrument. Three consecutive measurements were taken on each occasion, and the mean reading of the 3 recordings was used for subsequent analysis. A brief stretch into wrist extension was provided to all participants before measurement on each occasion. This brief stretch was conducted to reduce potential pain on measurement.[31] The measurement procedure used does not distinguish between the resistance caused by biomechanical and neural factors (ie, soft-tissue length changes and spasticity, respectively). Spasticity was not measured in isolation for a number of reasons. First, the main reason cited by therapists for making hand splints for this population is the prevention of contractures, not spasticity.[7] Second, traditional tools believed to measure spasticity (eg, the Ashworth or Modified Ashworth Scales) are also unable to distinguish between neural and biomechanical factors.[2,32] Third, there are also concerns about the validity, accuracy, and reliability of such measures.[2,33,34]

Upper-limb function was measured by using components 6 (upper-limb function), 7 (hand movements), and 8 (advanced hand activities) of the Motor Assessment Scale[35-37] (MAS). Psychometric properties of this scale have been investigated, and good reliability and validity have been established.[35,36] As required in the standardized procedure, 3 consecutive measurements were taken on each occasion, and the best performance was used in analysis. Each scale component was rated on a 0- to 6-point scale of increasing ability. Summed scores were then used to provide an indicator of overall upper-limb function.

Upper-limb pain was measured with a vertical visual analog scale[38,39] (VAS), which is a sensitive,[40,41] valid,[40,41] and reliable[41] method of collecting subjective pain intensity. This was recorded before measuring the wrist and finger flexor muscle length.

In addition to these clinical outcome measures, compliance with the splint-wearing schedule was recorded. Splint-wearing duration was logged daily on time-on/time-off recording charts by nursing staff on the hospital ward and was monitored by an investigator (NAL).

Data Analysis

Changes in the length of wrist and finger flexor muscles, upper-limb function scores, and pain scores in control and experimental groups were compared by using 2-tailed independent sample *t* tests. We also performed a secondary analysis of the differences between the 2 groups on the upper-limb function scores by using nonparametric Mann-Whitney test. Significance levels were pre-established at the $P \leq .05$ level. The size of the treatment effect was estimated by differences in group means and their 95% confidence intervals (CIs). Where possible, outcome measures were obtained for all subjects who participated in the trial. Each subject's data were analyzed in the group to which the subject was allocated, in accordance with the principle of intention to treat.[42,43]

RESULTS

Subjects in the 2 groups, on average, had similar characteristics at the time of recruitment to the study (table 1). Of the 28 subjects randomized, 25 (14 from the experimental group, 11 from the control group) participated in all interventions and assessments as allocated (fig 2). Outcome measures were obtained from 26 subjects after intervention and from 27 subjects at follow-up. One subject in the experimental group withdrew from the study during the intervention period as a result of self-discharge from the rehabilitation unit. Two additional subjects in the splint group refused postintervention measurement but participated in follow-up measurements (1 subject continued to receive interventions as allocated). One subject in the control group reported a pain rating of 0 at baseline and of 0 at postintervention and increased her rating by 100% (maximum score, 10) at the follow-up measure 1 week later. The follow-up value for pain differed so greatly that it was omitted from all analyses. The effects of splinting (the difference between the experimental and control groups) were not clinically important or statistically significant.

Table 1: Characteristics of Subjects in the Control and Experimental Groups at Study Commencement

Characteristics	Control Group (stretch only) (n=11)	Experimental Group (splint and stretch) (n=17)
Gender (male:female)	5:6 (45%:55%)	8:9 (47%:53%)
Mean age ± SD (y)	68±7.4	65±16.4
Mean days postimpairment ± SD	57±63.6	47±21.4
Dominant upper limb (left:right)	0:11 (0%:100%)	0:17 (0%:100%)
Affected upper limb (left:right)	7:4 (64%:36%)	7:10 (41%:59%)
Lesion location		
Frontoparietal area	1	2
Frontotemporoparietal area	1	0
Parietal lobe	1	1
Parietooccipital area	0	1
Temporal lobe	1	0
Temporoparietal area	1	1
Internal capsule	1	3
Unknown	5	4
Mean extension range ± SD (deg)	79±10.5	76±13.9
MAS* ± SD	0.8±1.8	1.8±3.0
Mean pain intensity† ± SD	1.6±2.7	2±2.9

NOTE. There were no significant differences between groups for any baseline variables.
* Cumulative score (maximum, 18).
† Centimeters on a 10-cm VAS.

Effect of Splinting on Contractures

Splinting increased wrist extension by a mean of 1° after the intervention (95% CI, −3.7° to 6.1°), and it reduced wrist extension by a mean of 2° at follow-up (95% CI, −7.2° to 3.2°).

Effect of Splinting on Function

Splinting decreased upper-limb function (MAS component 6) by a mean of 0.3 points after the intervention (95% CI, −1.5 to 0.9) and decreased upper-limb function by 0.8 points at follow-up (95% CI, −2.0 to 0.3). Splinting decreased performance of hand movements (MAS component 7) by 0.4 points after the intervention (95% CI,−1.4 to 0.7) and by 0.5 points at follow-up (95% CI, −1.5 to 0.6). Splinting decreased the performance of advanced hand activities (MAS component 8) by 0 points after the intervention (95% CI, −0.5 to 0.4) and by 0.1 point at follow-up (95% CI, −0.8 to 0.5).

Splinting decreased overall upper-limb function, measured by the summed scores of MAS, by 0.1 points after the inter-

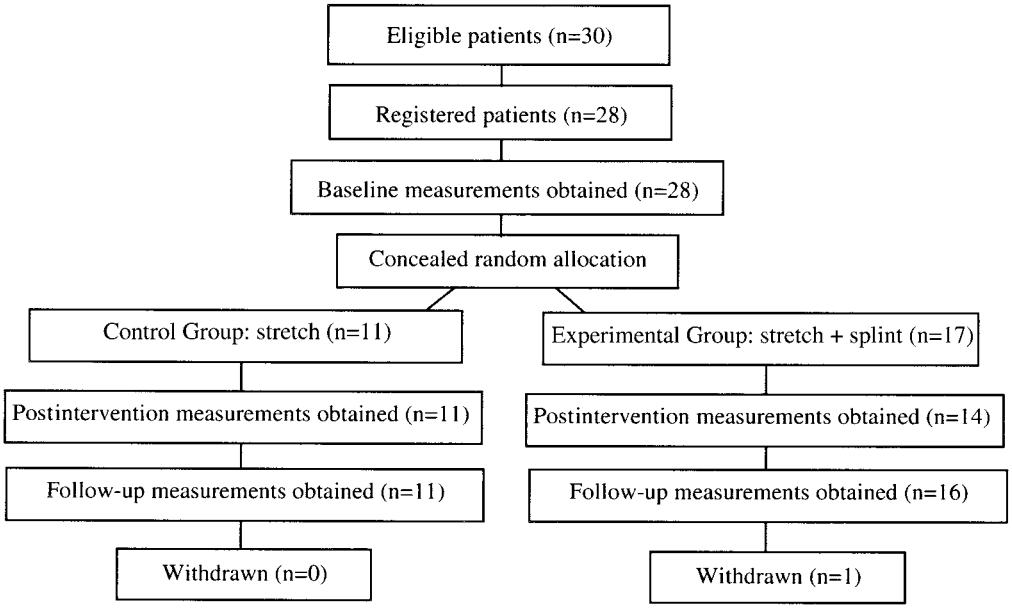

Fig 2. Trial profile.

vention (95% CI, −2.5 to 2.7) and by 0.2 points at follow-up (95% CI, −2.7 to 2.3). Nonparametric analyses yielded effects of 0 (median difference of all paired differences between groups) for all comparisons of MAS scores at both the final measurement and follow-up, and CIs for differences between medians[44] were similar to, or tighter than, those obtained with parametric analyses.

Effect of Splinting on Pain

Splinting increased the reported intensity of upper-limb pain by a mean of 0.2cm on a VAS after the intervention (95% CI, −2.3 to 2.7) and reduced the reported pain intensity by 1cm at follow-up (95% CI, −4.6 to 2.2).

Splint Compliance and Subject Satisfaction

All subjects in the experimental group wore hand splints, but, as could be expected in a clinical setting, there was some daily variability in individual adherence to the splinting protocol. Compliance with the splint-wearing protocol was, however, very high (table 2), and subjects seemed motivated to wear the splints with no additional encouragement. No subject in the experimental group showed evidence of skin breakdown or adverse reactions after splint wearing. On the contrary, the typical subjective response was that the splinting procedure was comfortable. At the end of the study, subjects in the experimental group were surveyed, and the annoyance level for splint wearing was measured. Fifteen participants rated annoyance of wearing the splint on a 10-cm VAS. The mean level of reported annoyance at the completion of the study was 3.9cm.

Table 2: Experimental Group Participation in Splint Wearing

	Mean Participation (h)	
Wear Time (Target Duration)	Mean ± SD	Median (Range)
Nightly (12h)	11±3	12 (0–13)
Weekly (48h)	74±14	81 (44–86)
Total (336h)	260±79	268 (44–336)

DISCUSSION

The major finding of this RCT was that subjects with acquired brain impairment who were participating in routine motor training and upper-limb stretches did not show detectable or important changes in wrist and finger flexor extensibility after wearing a splint daily for 4 weeks. Contrary to expectations, subjects in the control group did not lose wrist and finger flexor extensibility (ie, acquire a contracture) in this 4-week period if they did not wear a hand splint. The literature recommends that splints be worn for 2 to 6 hours a day in this population.[9,18] Splints were worn for up to 12 hours a day in this study (daily mean ± SD, 11±3h; range, 0–13h). Despite this intensive regimen of splinting, no significant differences between the control and experimental groups were detected.

Findings related to secondary study outcomes also indicated no effect. First, there was no evidence of clinically significant effects of splinting on upper-limb function, as measured by individual component or summed MAS scores. Second, the 4-week splint-wearing program did not significantly reduce upper-limb pain levels. It is acknowledged that the pain scores were low at baseline, which may have made reduction in pain difficult to detect. These 2 findings do suggest, however, that the practice of splinting to improve function[9,13,16,18,45] and to reduce pain levels[7,25,45] after acquired brain impairment should be questioned if patients are already receiving motor training and upper-limb stretches as part of their rehabilitation.

The absence of an effect after splint wearing on wrist and finger flexor extensibility may have been because the routine motor training and upper-limb stretches were already maintaining the length of the wrist and finger flexor muscles. These therapies may have rendered the additional stretch (the stretch provided by the hand splints) redundant. There is, however, no clear evidence that prolonged stretches prevent or reverse contracture of the wrist and finger flexor muscles after acquired brain impairment. Although a number of animal studies have found that short periods of daily stretching can prevent the development of muscle contracture,[46-51] clinical studies on human muscles have yet to show the same benefits. Further research is needed to determine whether prolonged stretching

at maximal wrist extension prevents or reduces contracture at the wrist in adults after acquired brain impairment.

There was a considerable range in time since impairment in the subjects recruited for this study, particularly within the control group. Nonetheless, the admission criteria ensured that all subjects were of similar upper-limb motor ability, with none having active wrist extension. The finding that splinting was not effective for increasing ROM when provided in addition to routine therapy specifically relates to the study population—patients with acquired brain injury without active wrist extension. This result does not suggest patient subgroups that may benefit from splinting. In addition to analyses of change scores, a priori covariate analysis of future studies may provide guidance relating to the effect of subject age and lesion type.

The results of this study suggest that splinting the hand in the functional resting position does not produce clinically useful effects in adults with acquired brain impairment. However, it could be that hand splinting in other positions that administer greater torque at the wrist may be beneficial. Further research studies should continue to use simple, accurate, and reliable assessment measures of torque-controlled ROM, motor function, and pain. Finally, the importance of replication of research findings[52] is acknowledged, given the statistically nonsignificant results.

CONCLUSION

This RCT showed that 4 weeks of hand splinting in the functional resting position does not improve contracture, hand function, or pain in adults with acquired brain impairment who are already participating in routine motor training and upper-limb stretches.

Acknowledgments: Appreciation is extended to the therapists and nursing staff at the Townsville Hospital Rehabilitation Unit, Queensland, for their cooperation and assistance with this study.

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Supplier

a. URIAS® Pressure Splint; Svend Andersen Plastic Industri, Maersk Medical A/S, Engmosen 1, 3540 Lynge, Denmark.