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# Effects of Splinting on Wrist Contracture After Stroke

## A Randomized Controlled Trial

Natasha A. Lannin, PhD; Anne Cusick, PhD; Annie McCluskey, PhD; Robert D. Herbert, PhD

**Background and Purpose**—Splints are commonly applied to the wrist and hand to prevent and treat contracture after stroke. However, there have been few randomized trials of this intervention. We sought to determine whether wearing a hand splint, which positions the wrist in either a neutral or an extended position, reduces wrist contracture in adults with hemiplegia after stroke.

**Methods**—Sixty-three adults who had experienced a stroke within the preceding 8 weeks participated. They were randomized to either a control group (routine therapy) or 1 of 2 intervention groups (routine therapy plus splint in either a neutral or an extended wrist position). Splints were worn overnight for, on average, between 9 and 12 hours, for 4 weeks. The primary outcome, measured by a blinded assessor, was extensibility of the wrist and long finger flexor muscles (angle of wrist extension at a standardized torque).

**Results**—Neither splint appreciably increased extensibility of the wrist and long finger flexor muscles. After 4 weeks, the effect of neutral wrist splinting was to increase wrist extensibility by a mean of 1.4° (95% CI, -5.4° to 8.2°), and splinting the wrist in extension reduced wrist extensibility by a mean of 1.3° (95% CI, -4.9° to 2.4°) compared with the control condition.

**Conclusions**—Splinting the wrist in either the neutral or extended wrist position for 4 weeks did not reduce wrist contracture after stroke. These findings suggest that the practice of routine wrist splinting soon after stroke should be discontinued. (*Stroke*. 2007;38:111-116.)

**Key Words:** function ■ pain ■ occupational therapy ■ upper limb disability ■ spasticity

Hemiplegia is often associated with contracture.<sup>1</sup> The joints most prone to contracture are the wrist and ankle.<sup>2</sup> Contractures of the arm are more prevalent than those of the leg.<sup>3</sup> Wrist flexion contractures develop rapidly after stroke in people who have no early movement recovery.<sup>1</sup>

To prevent contractures, people who have had a stroke are often prescribed wrist splints to wear at night.<sup>4-6</sup> Wrist splints are thought to prevent or reduce contracture, and the belief is that this will contribute to hand function, should motor recovery occur. Because the aim of splinting is to influence muscle extensibility, the degree of stretch provided by the splint is important. Some therapists believe that positioning a muscle close to its end of range will provide a greater effect on contracture.<sup>6,7</sup>

The efficacy of hand splinting after stroke has been examined in several reviews.<sup>8-10</sup> Each review has concluded that there is insufficient evidence to either support or refute the effectiveness of hand splinting. Published trials either did not include a no-stretch control group<sup>11-13</sup> or suffered from methodological limitations such as short follow-up,<sup>13</sup> lack of blinded assessment of outcomes,<sup>11,13,14</sup> or low statistical

power.<sup>11,13,14</sup> We have previously published a trial of hand splinting with the wrist in neutral, which found no difference in outcomes between groups who received splinting plus hand stretching versus stretching alone.<sup>12</sup> Although adequately powered with blinded assessment of outcomes, the study did not compare the effect of splinting with a no-splint control group.

The aim of the current study was to determine the effect of 4 weeks of night splinting on contracture in the wrist and long finger flexor muscles in adults after stroke. Because there is uncertainty about whether the degree of stretch applied to splinted muscles is important, we also sought to determine whether splinting the wrist in an extended position was more effective than splinting the wrist in a neutral position.

### Subjects and Methods

The study was an assessor-blind, randomized, controlled, multicenter trial. The trial was undertaken from October 2002 through to September 2004 in 9 inpatient rehabilitation and stroke units in Sydney, Australia.

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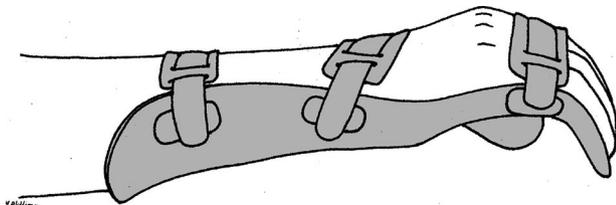


Figure 1. Neutral wrist splint.

## Participants

Sixty-three inpatients were recruited. To be included in the trial, participants had to have had a stroke within the previous 8 weeks; have been aged 18 years or older; have had no active wrist extension; have had sufficient cognitive and hearing function to be able to provide informed consent and fully participate in the trial; and to have resided in the greater Sydney metropolitan area. The sample size of 63 participants was sufficient to provide a 95% probability of detecting a 5° change in wrist extension, assuming a within-group standard deviation of 4.1°,<sup>12</sup> an  $\alpha$  of 0.05, and a loss to follow-up of 20%.

Participants were randomly assigned to 1 of 3 equally sized groups after baseline assessments were made: a neutral splint group, an extension splint group, or a control group. The allocation schedule was computer generated and concealed in opaque, consecutively numbered envelopes by a person not otherwise involved in the study.

Informed consent was obtained from each participant or, where appropriate, his or her legal guardian. The respective institutional review boards approved the study protocol at each institution.

## Intervention

Participants in both splint groups wore custom-made, static, palmar mitt splints<sup>15</sup> for up to 12 hours overnight for the 4-week intervention period. Participants in the neutral splint group wore a hand splint, which positioned the wrist in 0° to 10° extension<sup>16,17</sup> (Figure 1). Participants in the extension splint group wore a hand splint, which positioned the wrist in a comfortable end-of-range position (>45° wrist extension; Figure 2) with the metacarpophalangeal and interphalangeal joints extended.

Control group participants did not wear a hand splint for the study period. Participants in all 3 groups received usual rehabilitation, except that stretches of the wrist or long finger flexor muscle were not performed during the 6-week study period. A maximum of 10 minutes of isolated wrist and finger extension practice was permitted per day in line with usual rehabilitation practices at the participating centers.

## Outcomes

Measures were assessed at baseline (before randomization), after 4 weeks of intervention (12 to 24 hours after removal of the splint),

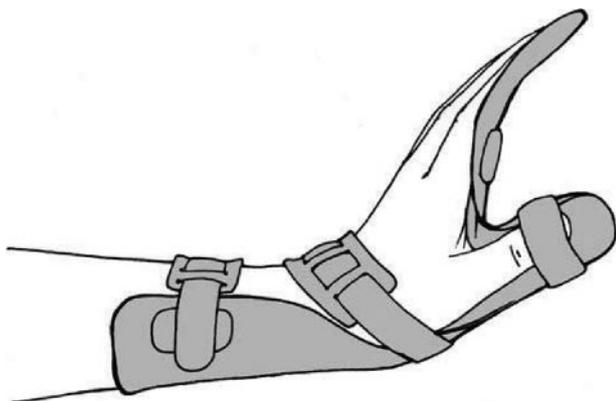


Figure 2. Extended wrist splint.

and 6 weeks after randomization by an independent assessor who was unaware of which treatment the patient had received.

The primary outcome was extensibility of the wrist and finger flexor muscles. Muscle extensibility was determined by measuring wrist extension range with the metacarpophalangeal and interphalangeal joints in the extended position. A standardized torque was applied by using a device specifically designed for the purpose and previously tested for test-retest reliability (intraclass correlation coefficient=0.85).<sup>18</sup> The method has been described in detail elsewhere.<sup>12,18</sup> In this study, the angle of wrist extension was measured from lateral photographs. Three consecutive measurements were taken on each occasion, and the mean of the 3 recordings was used for subsequent analysis.

Secondary measures included upper limb function, spasticity, and self-reported disability and symptoms. Upper limb function was assessed by summing scores of the 3 upper limb items of the Motor Assessment Scale (upper arm function, hand movements, advanced hand activities items),<sup>19</sup> yielding a score of 0 to 18. The reliability and validity of this assessment scale have been established.<sup>19–21</sup> Spasticity was measured with the Tardieu scale.<sup>22,23</sup> The Tardieu scale yields both a spasticity rating and a spasticity angle. The spasticity rating quantifies muscle tone by measuring the intensity of the muscle reaction at specified velocities and is a score between 0 (no resistance) and 4 (unfatigable clonus at a precise angle). The difference between the angle of arrest of the joint at slow speed and the angle of catch at fast speed is called the spasticity angle. The spasticity angle provides an estimation of the relative contribution of neural mechanisms (spasticity) and the mechanical restraint of the soft tissues (the larger the spasticity angle, the greater the contribution of spasticity). The Tardieu scale is a valid clinical measure of spasticity after stroke.<sup>24</sup> Disability was assessed with the Disabilities of the Arm, Shoulder, and Hand Outcome Measure (DASH).<sup>25</sup> The DASH consists of a 30-item disability/symptom scale that is transformed to a percentage score ranging from 0 (no disability) to 100 (most severe disability). Pain scores were obtained from the DASH pain severity item (recorded as a percentage, with higher scores indicating greater perceived severity of pain at rest). Research has demonstrated the validity, reliability, and responsiveness of the DASH for clinical and research purposes.<sup>26–28</sup>

## Data Reduction and Analysis

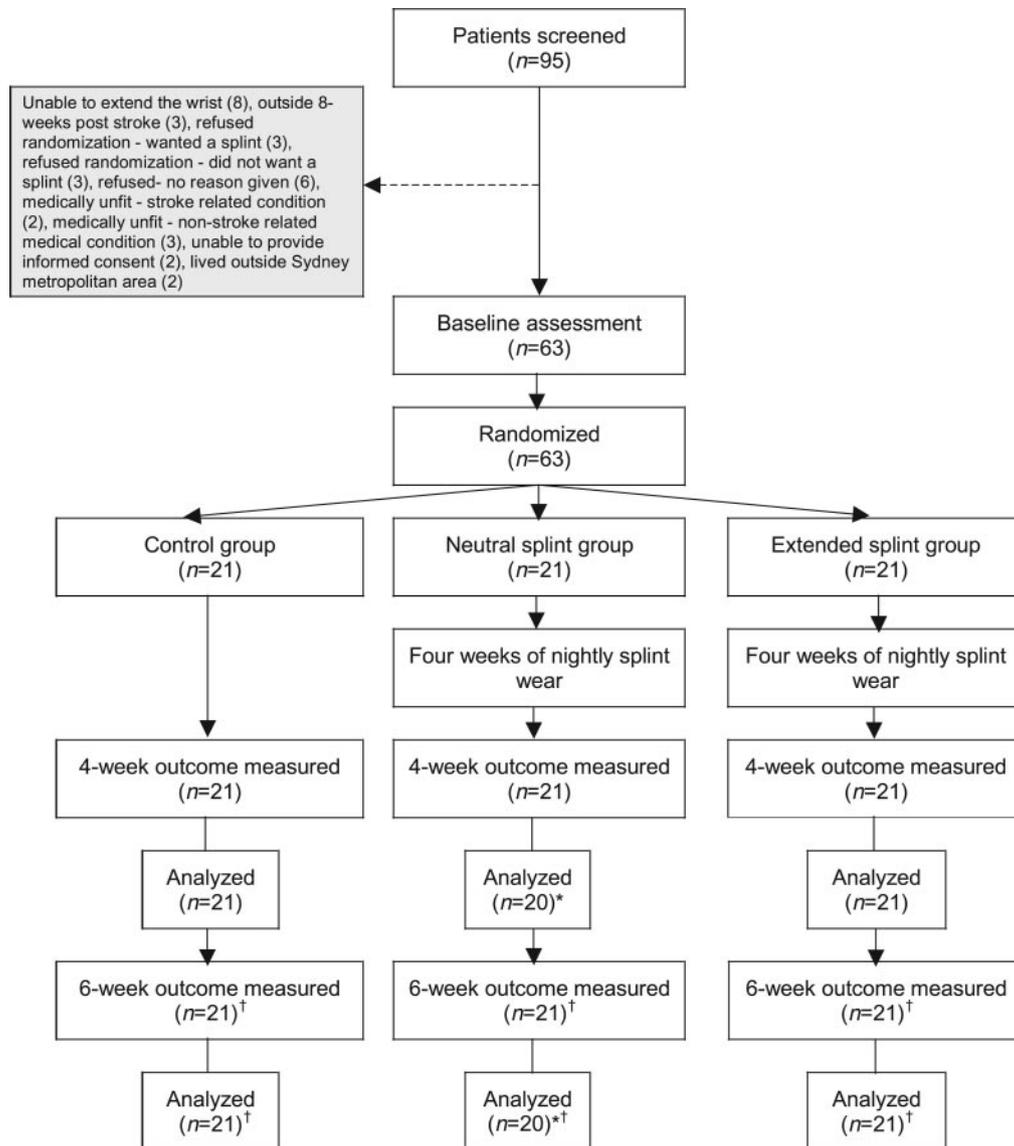
Data were analyzed on an intention-to-treat basis.<sup>29</sup> Thus, outcome measures were obtained for all participants recruited to the trial, irrespective of compliance, and participants' data were analyzed in the group to which they had been allocated. To determine the effects of splinting, we conducted an ANCOVA with the baseline extensibility score as a covariate to increase the precision of the estimate. Statistical significance was set at  $P < 0.05$ .

## Results

Of 95 people screened, 82 were identified as eligible, and 63 agreed to participate and were randomized to the 3 groups (Figure 3). The groups were similar at baseline (Table 1).

No participant withdrew from the study. One participant in each group refused the primary outcome measure at 6 weeks only (4.8% of sample). One participant in the neutral splint group had his diagnosis of stroke revised by a physician who was not involved in the study and who was blinded to treatment allocation. Data were therefore excluded from analyses, in line with recommendations on acceptable post-randomization exclusions in the application of intention-to-treat analysis.<sup>30</sup>

The trial protocol dictated that participants receive 28 nights of splinting to the hemiplegic wrist of up to 12 hours per night: a total maximum time of 336 hours of splinting. Overall, there was high compliance with the splinting regimen. Participants wore their splints for a mean of 10 hours, 11



**Figure 3.** Flow of participants through the trial. \*One participant was randomized to the neutral splinting program but not included in the primary analysis after revision of the initial diagnosis of stroke by an independent physician blinded to treatment and outcome. †One participant from each group refused to complete the primary outcome measure at follow-up; all secondary measurements were completed.

minutes per night (SD, 2.0 hours). There was higher compliance with the neutral splint (mean, 11.0 hours; SD, 1.1 hours) than with the extension splint (mean, 9.4 hours; SD, 2.3 hours; difference, 1.7 hours; 95% CI, 0.5 to 2.8 hours). Outcomes of all participants were assessed within 2 days of the final night of splinting.

### Primary Outcome

On average, participants experienced a moderate loss of range of motion (mean, 16.7°; SD, 15.1°) during the 6-week study period. Splinting had little or no effect on the loss of range of motion (Figure 4). The mean effect in the neutral splint group was 1.4° (95% CI, -5.4° to 8.2°) at 4 weeks and 4.2° (95% CI, -3.2° to 11.7°) at follow-up compared with the control group. The mean treatment effect in the extension splint group was -1.3° (95% CI, -4.9° to 2.4°) at 4 weeks and 1.8° (95% CI, -3.4° to 5.1°) at follow-up compared with the control group.

### Secondary Outcomes

The effects of splinting on secondary outcomes (upper limb function, spasticity, and self-reported disability and symptoms) were clinically unimportant and statistically nonsignificant (Table 2).

### Discussion

The primary finding of this study is that an intensive 4-week splinting program did not increase the extensibility of the wrist and long finger flexor muscles in adults after stroke.

On average, participants in the trial lost 17° of wrist range of motion by the end of the 6-week study. This finding of progressive loss of muscle extensibility in the hemiplegic upper limb after stroke is not new. Turton and Britton,<sup>31</sup> in their trial evaluating stretch positioning in the upper limb, reported a loss of 13° of wrist extension range and 15° of shoulder external rotation range at 8 weeks,

**TABLE 1. Baseline Characteristics of the Study Groups**

	Control (n=21)	Neutral Splint (n=20)	Extension Splint (n=21)
Mean age, y (SD)	75.4 (11.0)	70.3 (12.6)	68.7 (12.1)
Sex, No. of women (%)	12 (57)	11 (52.3)	9 (42.8)
Time poststroke at randomization, mean No. of days (SD)	30 (13.3)	27.8 (14.5)	25 (11.6)
Mini-Mental State Examination, mean score (SD)	22 (5.9)	21.9 (5.4)	24.5 (3.6)
Canadian Neurological Scale: mean score (SD)	4.6 (1.3)	4.4 (1.5)	4.9 (1.1)
Dominance, No. of participants with right-hand dominance (%)	20 (95.2)	19 (90.5)	21 (100)
No. of participants with right-sided hemiplegia (%)	11 (52.3)	10 (47.6)	10 (47.6)
Education, mean No. of years of education, including school (SD)	10.3 (3.2)	8.1 (4.7)	10.5 (3.6)
Ethnicity, No. from a non-English-speaking background (%)	7 (33.3)	11 (52.4)	9 (42.9)
Unaffected wrist extensibility in degrees, mean (SD)	64.5 (10.1)	65.8 (12.3)	65.2 (15.0)
Wrist extensibility in degrees, mean (SD)	56.2 (15.0)	62.1 (16.4)	56.8 (12.4)
UL-MAS, mean total score/18 (SD)	0.1 (0.3)	0.3 (0.9)	0.3 (0.4)
Tardieu scale			
Spasticity rating, median rating/4 (interquartile range)	1 (1)	1.5 (2)	1 (2)
Spasticity angle, mean degrees (SD)	-1.2 (1.1)	-0.9 (1.5)	-0.8 (1)
Pain, mean percentage (SD)	52 (32)	44 (34)	58 (32)
DASH, mean total score/100 (SD)	60.8 (21.7)	57.6 (24.0)	62.8 (24.4)

UL-MAS indicates Upper Limb-Motor Assessment Scale.

regardless of whether or not participants received prolonged stretching. Ada and colleagues<sup>7</sup> also reported a progressive loss of shoulder range of motion in their trial. Participants who were receiving shoulder stretches to

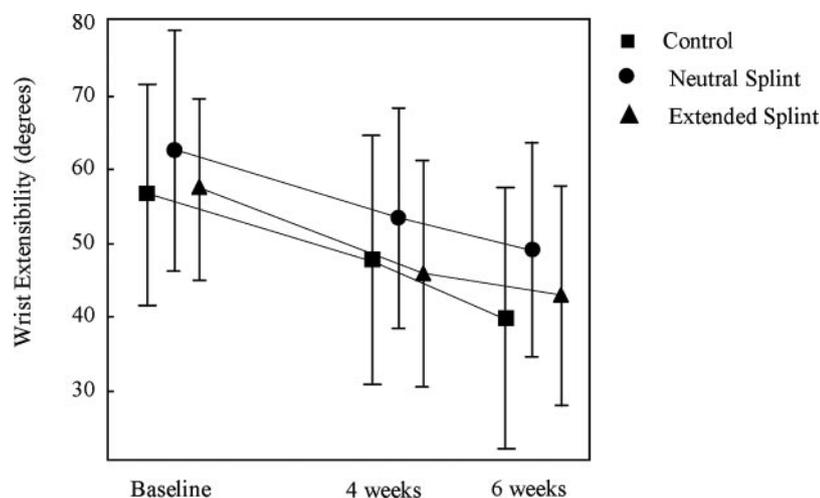
prevent loss of external rotation for 30 minutes, 5 days a week, lost an average of 6° of range over 4 weeks; those receiving shoulder flexion stretches lost nearly 12° of range on average.<sup>7</sup>

**TABLE 2. Outcome Scores and Estimates of Effects of All Outcome Measures for the Control Group (n=21), Neutral Splint Group (n=20), and Extended Splint Group (n=21)**

Outcome	Outcome Score			ANCOVA-Adjusted Estimates of Effects*		
	Control	Neutral Splint	Extended Splint	Control vs Neutral	Control vs Extended	Neutral vs Extended
Wrist extensibility in degrees, mean (SD)						
4 weeks	47.3 (16.9)	53.1 (14.9)	45.5 (15.4)	1.4 (-5.4 to 8.2)	-1.3 (-4.9 to 2.4)	-4.4 (-11.9 to 3.1)
6 weeks	39.4 (17.8)	48.8 (14.5)	42.5 (14.9)	4.2 (-3.2 to 11.7)	0.8 (-3.4 to 5.1)	-2.6 (-8.9 to 3.7)
Function, UL-MAS mean total score (SD)						
4 weeks	0.4 (0.9)	0.9 (2.0)	0.7 (1.4)	-0.1 (-0.7 to 0.6)	0.0 (-0.4 to 0.4)	-0.1 (-0.8 to 0.7)
6 weeks	0.5 (±0.8)	1.5 (±4.3)	0.8 (±2.0)	0.0 (-1.03 to 1.07)	0.1 (-0.4 to 0.5)	-0.3 (-1.6 to 0.9)
Tardieu spasticity angle, mean degrees (SD)						
4 weeks	2.4 (±16.7)	7.7 (±8.5)	6.3 (±8.4)	4.1 (-3.5 to 11.8)	1.3 (-2.2 to 4.9)	-1.4 (-5.6 to 2.7)
6 weeks	9.6 (±10.1)	9.5 (±7.4)	4.7 (±9.3)	-1.3 (-6.7 to 4.1)	-2.5 (-5.5 to 0.4)	-3.9 (-9.3 to 1.5)
Tardieu spasticity rating, median (interquartile range)						
4 weeks	2 (1)	2 (2)	2 (1)	...	...	...
6 weeks	2 (0.3)	2 (0.5)	2 (1)	...	...	...
Pain, mean percentage (SD)						
4 weeks	63.5 (31.0)	56.3 (28.0)	58.3 (28.8)	-9.6 (-33.4 to 14.0)	7.5 (0.3 to 14.7)	0.4 (-23.5 to 24.8)
6 weeks	65.9 (27.1)	61.7 (21.6)	53.3 (21.6)	-8.0 (-29.7 to 13.7)	-5.6 (-15.3 to 4.0)	-2.5 (-24.8 to 19.7)
DASH, mean total score (SD)						
4 weeks	66.8 (17.4)	58.5 (19.4)	60.4 (12.4)	-7.9 (-20.2 to 4.4)	-3.4 (-9.4 to 2.6)	1.2 (-12.1 to 14.7)
6 weeks	67.0 (19.8)	56.5 (22.9)	58.0 (18.9)	-5.3 (-18.8 to 8.2)	-4.9 (-11.3 to 1.4)	-4.7 (-19.2 to 9.7)

UL-MAS indicates Upper Limb-Motor Assessment Scale.

\*Between-group differences were adjusted for the baseline value of the outcome.



**Figure 4.** Mean (SD) of wrist extension of all groups at commencement of the study (baseline), then after 4 weeks of splint intervention (end of treatment), and then 2 weeks after removal of the splint (follow-up).

Splinting the wrist in extension for an average of 9 hours overnight did not result in an increase in range of movement. Current thinking, based on animal studies, is that muscle length adapts to stretch.<sup>32–34</sup> It has been hypothesized that longitudinal muscle growth occurs in response to the average position in which a muscle is held.<sup>35</sup> However, results from the current trial are contrary to findings predicted by this model. The results are consistent with a number of high-quality, randomized, controlled trials on neurological populations, all of which have shown that stretching programs do not produce clinically important effects on joint range of motion or muscle extensibility.<sup>12,31,36–38</sup> After an earlier trial of hand splinting for stroke patients, which found that splinting was ineffective,<sup>12</sup> we speculated that hand splints that administered greater stretch at the wrist might be beneficial. In the current study, extension splints were monitored on a weekly basis and remolded to maintain stretch and maximize torque. Despite this, we have shown that splinting the wrist in either a neutral or an extended position did not produce clinically useful effects in adults after stroke.

The effects of splinting on spasticity were not statistically significant or clinically important. The common belief that hand splinting reduces spasticity<sup>6,16,39</sup> was therefore not supported by this study.

The strengths of this study are that it used a concealed, random allocation to intervention and control groups, blinded assessment of outcomes, used valid outcome measures, had complete follow-up, specified primary outcomes a priori, and analyzed data by intention to treat. Also, the patients were representative of those for whom splints might be considered, and the intervention (at least of neutral splinting) resembled that commonly used in clinical practice. Therefore, the results should be generalizable to the stroke population undergoing acute rehabilitation. One limitation was that participants were not blinded. This would have been difficult or impossible. Nonblinding of participants raises the possibility of bias attributable to placebo effects and differential misreporting of subjective outcomes. Differential misreporting of outcomes could not have substantially biased the findings because the majority of outcomes were objective measures (not self-reported) obtained by blinded assessors.<sup>40</sup>

This trial involved splinting participants for 4 weeks. Longer-term effects of splinting were not examined. Nonetheless, we believe that the intervention was applied for a long enough period to observe an effect of intervention, if such an effect exists, because we observed moderate losses of wrist range of motion during the same time period.

### Summary

The results of this study demonstrate that 4 weeks of overnight splinting in either a neutral or an extended wrist position does not prevent loss of range of motion at the wrist and that the use of a splint is no better than not splinting. These findings suggest that the routine practice of hand splinting to prevent muscle contracture during acute rehabilitation after stroke should be discontinued.

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### Disclosures

None.

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