

Splinting for the prevention and correction of contractures in adults with neurological dysfunction: practice guideline for occupational therapists and physiotherapists

Quick Reference Guide



The Quick Reference Guide provides a summary of the recommendations in the practice guideline for occupational therapists and physiotherapists on ***Splinting for the prevention and correction of contractures in adults with neurological dysfunction*** (COT and ACPIN 2015). It is intended to be used by practitioners as an easily accessible reminder of the recommendations for intervention. It should ideally be used once the practitioner has read the full guideline document. This is important to ensure an appreciation and understanding of how the recommendations were developed and their context.

The full practice guideline together with implementation resources can be accessed from the College of Occupational Therapists website: <http://www.cot.co.uk/library-publications/cot-publications/practice-guidelines> and the Association of Chartered Physiotherapists in Neurology (ACPIN) website: www.acpin.net

College of Occupational Therapists and Association of Chartered Physiotherapists in Neurology (2015) *Splinting for the prevention and correction of contractures in adults with neurological dysfunction: practice guideline for occupational therapists and physiotherapists*. London: COT.

1. Introduction

The objective of this practice guideline is to provide evidence-based recommendations that inform occupational therapists and physiotherapists, working with adults with neurological dysfunction, when considering the process of splinting for the prevention and correction of contractures. The recommendations are intended to be used alongside the therapist's clinical expertise in their assessment of need and implementation of interventions. The therapist is, therefore, ultimately responsible for the interpretation of the evidence-based guideline in the context of their specific circumstances and service users. This guideline does not provide practical information on how to undertake splinting.

It is intended that occupational therapists and physiotherapists use this guideline to inform their work with service users, with a particular focus on empowering the service user to fully engage and take responsibility for achieving individual goals. The application of this guideline will also inform the commissioning and delivery of evidence-based services.

This resource provides a quick reference to the guideline recommendations, together with tables outlining the nature of the strength and quality grading categories of the recommendations. Extracts from the full guideline document on the clinical background and an overview of the occupational therapy and physiotherapy role are also provided. Evidence-based recommendations are, however, not intended to be taken in isolation and must be considered in conjunction with the contextual information, and full guideline development methodology, described in the practice guideline

document, together with current versions of professional practice documents, of which knowledge and adherence is assumed (COT and ACPIN 2015, p11).

The studies from which the recommendations were developed are outlined in the full guideline in evidence tables (Appendix 7). 40% of the evidence used was derived from studies of high or moderate quality: 12% of the evidence was graded as high (A), 28% as moderate (B), 36% as low, and 24% as very low (D). All nineteen of the recommendations are graded as conditional.

Research priorities identified during the development of the guideline are outlined in the full guideline document (COT and ACPIN 2015, p51).

It is intended that this practice guideline provides a comprehensive practical resource for occupational therapists, physiotherapists and the multidisciplinary team working with adults with a neurological health condition who have or are at risk of developing contractures.

As splinting is largely a postgraduate clinical skill, all therapists must ensure they work within their scope of practice and, where appropriate, seek supervision from more senior staff. Practical splinting training should be undertaken as necessary.

2. Guideline recommendations

The recommendations are based on the synthesis of the best available evidence. It should, therefore, be noted that the guideline is not able to be fully reflective of the role of occupational therapy and physiotherapy in the prevention and correction of contractures in adults with neurological dysfunction.

The seven recommendation categories reflect key aspects of occupational therapy and physiotherapy in the prevention and correction of contractures in adults with neurological dysfunction, and are divided as follows:

Lower limb

- i. Ankle contracture correction.
- ii. Ankle contracture prevention.
- iii. Knee contracture correction.
- iv. Knee contracture prevention.

Upper limb

- v. Hand and wrist contracture correction.
- vi. Hand and wrist contracture prevention.
- vii. Elbow contracture correction.

Lower limb Recommendations are graded A (high) to D (very low) to indicate the quality of the evidence, and the scoring of 1 (strong) or 2 (conditional) indicates the strength of the recommendation.
Ankle: contracture correction
1. It is suggested that ankle casts are used at end range (for people with ABI and stroke) for improving range of movement at the ankle joint. 2C <i>(Booth et al 1983 [D] ABI; Carda et al 2011 [B] stroke; Lehmkuhl et al 1990 [D] ABI; Moseley 1993 [C] ABI; Moseley et al 1997 [B] ABI; Pohl et al 2002 [C] ABI and stroke; Singer et al 2003a [B] stroke and ABI; Singer et al 2003b [C] stroke and ABI; Verplancke et al 2005 [B] ABI; Yasar et al 2010 [D] stroke)</i>

2.	It is suggested that ankle casts are applied at end range to improve joint range of movement in conjunction with botulinum toxin A (in people with stroke and ABI) when presenting with clinically significant spasticity (see also RCP 2009). <i>(Carda et al 2011 [B] stroke; Farina et al 2008 [B] stroke; Verplancke et al 2005 [B] ABI; Yasar et al 2010 [D] stroke)</i>	2B
3.	It is suggested that adjustable ankle splints applied at end range can be used (in people with stroke and ABI) for improving joint range of movement. <i>(Grissom and Blanton 2001 [D] stroke and ABI; Lai et al 2008 [C] ABI and stroke)</i>	2C
4.	It is suggested that caution is exercised when considering the use of non-custom-made splints for the correction of contractures (at the ankle in people with stroke and ABI) due to the risk of pressure sores. <i>(Grissom and Blanton 2001 [D] stroke and ABI)</i>	2D
Ankle: contracture prevention		
5.	It is suggested that ankle casts at end range dorsiflexion (in people with acute ABI) can prevent loss of range of movement. <i>(Conine et al 1990 [C] ABI)</i>	2C
6.	It is suggested that an ankle splint can be used for preventing the loss of range of movement at the ankle joint (in people with stroke) when positioned at plantar grade. <i>(Robinson et al 2008 [B] stroke)</i>	2B
7.	It is suggested that caution is exercised when considering the use of non-custom-made splints for the prevention of contractures (at the ankle in people with stroke) due to the risk of pressure sores. <i>(Robinson et al 2008 [B] stroke)</i>	2B
Knee: contracture correction		
8.	It is suggested that casts may be used for the correction of contracture (in people with ABI and stroke) with the knee joint positioned at end range of movement. <i>(Booth et al 1983 [D] ABI; Lehmkuhl et al 1990 [D] ABI; Pohl et al 2002 [C] ABI and stroke)</i>	2D
9.	It is suggested that short-duration cast application (1-4 days) may produce a lower complication rate than longer duration cast application (4-7 days). <i>(Pohl et al 2002 [C] ABI and stroke)</i>	2C
Knee: contracture prevention		
10.	It is suggested that casts at end range of movement at the knee joint may be used (in people with stroke and ABI) for the prevention of contracture. <i>(Pohl et al 2002 [C] stroke and ABI)</i>	2C
11.	It is suggested that caution is used when considering casts for acute patients (with ABI and stroke) and at lower levels of arousal because of possible risks of secondary complications (e.g. pressure areas). <i>(Pohl et al 2002 [C] stroke and ABI)</i>	2C

Upper limb	
<i>Recommendations are graded A (high) to D (very low) to indicate the quality of the evidence, and the scoring of 1 (strong) or 2 (conditional) indicates the strength of the recommendation.</i>	
Hand and wrist: contracture correction	
12. It is suggested that splints should not be used routinely for the correction of range of movement but may be beneficial in selected cases (in people with stroke and ABI).	2B
<i>(Abdolvahab et al 2010 [D] stroke; Amini et al 2009 [D] stroke; Beaty and Murphy 2013 [C] stroke; Bürge et al 2008 [A] stroke; Charait 1968 [D] stroke; Doucet and Mettler 2013 [C] stroke; Fayez and Sayed; 2013 [C] stroke; Lannin et al 2007a [A] stroke; Lannin et al 2003 [B] stroke and ABI; Leung et al 2012 [A] stroke and ABI; Shamila et al 2011 [D] stroke)</i>	
Hand and wrist: contracture prevention	
13. It is suggested that splints should not be used routinely to prevent loss in range of movement at the wrist and hand (people with stroke and ABI) but may be beneficial in selected cases.	2B
<i>(Basaran et al 2012 [B] stroke; Bürge et al 2008 [A] stroke; Harvey et al 2006 [A] stroke and ABI; Lannin et al 2007a [A] stroke; Lannin et al 2003 [B] stroke and ABI; Shamila et al 2011 [D] stroke)</i>	
14. It is suggested that splints in conjunction with botulinum toxin A (in people with stroke and ABI) may reduce spasticity as a component in preventing loss of range of movement in selected cases.	2C
<i>(Carda and Molteni 2005 [C] stroke and ABI)</i>	
15. It is suggested that electrical stimulation of wrist and finger muscles combined with a custom-made wrist and hand splint should not be used routinely to prevent loss in range of movement (in people with stroke or ABI).	2A
<i>(Leung et al 2012 [A] stroke and ABI)</i>	
16. It is suggested that a custom-made wrist and hand splint should not be used routinely to prevent the increase (or worsening) of spasticity (in people with stroke and ABI).	2B
<i>(Basaran et al 2012 [B] stroke; Bürge et al 2008 [A] stroke; Jung et al 2011 [C] stroke; Leung et al 2012 [A] stroke and ABI; Shamila et al 2011 [D] stroke)</i>	
17. It is suggested that a splint in a neutral wrist position may be beneficial (for people with stroke) for prevention of hand pain associated with joint malalignment.	2A
<i>(Bürge et al 2008 [A] stroke)</i>	
Elbow: contracture correction	
18. It is suggested that casts at end range are used (for people with ABI and stroke) for improving range of movement at the elbow joint.	2C
<i>(Hill 1994 [C] ABI; Lehmkuhl et al 1990 [D] ABI; Moseley et al 2008 [B] ABI; Pohl et al 2002 [C] ABI and stroke)</i>	
19. It is suggested that short-duration cast application (1-4 days) may produce a lower complication rate than longer-duration cast application (4-7 days).	2C
<i>(Pohl et al 2002 [C] ABI and stroke)</i>	

3. Recommendation grade guide

Strength of grade (after Guyatt et al 2008)

Strength	Grade	Benefits and risks	Implications
Strong	1 'It is recommended...'	Benefits appear to outweigh the risks (or vice versa) for the majority of the target group.	Most service users would want or should receive this course of intervention or action.
Conditional	2 'It is suggested....'	Risks and benefits are more closely balanced, or there is more uncertainty in likely service user values and preferences.	The majority of service users would want this intervention but not all, and therefore they should be supported to arrive at a decision for intervention consistent with the benefits and their values and preferences.

GRADE quality of evidence grading (after GRADE Working Group 2004)

Quality of evidence	Grading	Characteristics	Confidence
High	A	Based on consistent results from well-performed randomised controlled trials, or overwhelming evidence of an alternative source e.g. well-executed observational studies with strong effects.	True effect lies close to that of the estimate of the effect. Further research very unlikely to change confidence in the estimate of the effect.
Moderate	B	Based on randomised controlled trials where there are serious flaws in conduct, inconsistency, indirectness, imprecise estimates, reporting bias or some other combination of these limitations, or from other study designs with special strengths.	True effect likely to be close to the estimate of the effect, but there could be a substantial difference. Further research is likely to have an important impact on confidence in the estimate of effect and may change the estimate.
Low	C	Based on observational evidence, or from controlled trials with several very serious limitations.	True effect may be substantially different from the estimate of the effect. Further research very likely to have an important impact on confidence in the estimate of the effect and is likely to change the estimate.
Very low	D	Based on case studies or expert opinion.	Any estimate of effect is very uncertain and may be far from the true effect.

It is recommended that occupational therapists and physiotherapists participate in national and local audit of neurological services, and use the tool which is available to support this guideline to undertake audit against the information provided in section 6 of this Quick Reference Guide.

Information about organisational and financial barriers that may impact on an occupational therapist's and physiotherapist's ability to implement the recommendations are outlined in the full guideline (COT and ACPIN 2015, pp48-49).

4. Clinical background

Contracture is a common secondary complication of paresis and weakness following nervous system damage (Lieber 2010). The inability to move joints through a full range of movement due to weakness is a primary contributor to contracture. To help people maintain their level of function and independence, muscles and joints must maintain their length and range of movement to limit the adverse effects of stiffness from secondary complications (Pitts and O'Brien 2008). **Contracture** is defined as a limitation in passive range of joint movement (Halar and Bell 1988). Contracture formation is complex, and a number of structures can be involved, including the joint capsule, joint ligaments, muscles and tendons (Farmer and James 2001). Contractures in the early stages of development have been described as having elements of thixotrophy and therefore being more adaptable to change. The term 'thixotrophy' has been applied to substances that can be changed from a gel-like substance to a solution after being stirred (Vattanasilp et al 2000). Muscle, although clearly not a gel or solution, has been described as behaving as a thixotropic substance in that its stiffness depends on the history of limb movement. Lakie and Robson (1988) found that when stretch was applied to a relaxed muscle that had been maintained in a shortened position, initial resistance to movement was high. Conversely, with muscle in a lengthened position, the initial resistance was lower. Clinically an increased resistance to passive movement would be felt on initially moving a limb; after stretch has been applied, however, this relative stiffness is decreased. Over time, contractures may develop and the muscle is then less amenable to alteration.

In addition, the presence of positive signs of the upper motor neuron syndrome (UMNS) i.e. spasticity, can play a role in the development of non-neural adaptations seen with decreasing range of movement (Ada et al 2006, Kilbride and Cassidy 2011). Spasticity is defined as a disordered sensori-motor control resulting from an upper motor neuron lesion, presenting as intermittent or sustained involuntary activation of muscles (Pandyan et al 2005).

Splinting is an intervention used in the prevention and correction of contracture in adults with a neurological condition (Coppard and Lohman 2008, Edwards and Charlton 2002). Splinting is defined as the 'application of external devices designed to apply, distribute or remove forces to or from the body in a controlled manner, to perform one or both functions of control of body motion and alteration or prevention in the shape of the body tissue' (Rose 1986). The focus of this guideline is alteration or prevention in the shape of body tissue. Splinting may be applied for the control of body motion by therapists or orthotists, but this is not covered in this guideline.

In the context of this guideline, the aim of splinting is to correct and prevent contractures and in doing so facilitate improved function through increased range of movement. The rationale underpinning splinting is to provide a prolonged stretch to maintain or promote change in a body structure (the theoretical basis of splinting is explored in more detail in Section 3 of the full guideline). Depending on the rationale for splinting and the individual clinical presentation, splinting may be used in conjunction with other therapeutic adjuncts such as botulinum toxin or a regular standing programme. In some cases where contracture has become established resulting in fixed joint deformity, conservative means (i.e. splinting) are not sufficient to produce change where this is the goal. In these instances, it may be appropriate to consider surgical intervention; this does not fit within the remit of this document and will require referral to an orthopaedic surgeon. Following splinting or surgical intervention for contracture, long-term orthotic provision may be required for continued maintenance of joint range and function. Referral to an orthotist as part of overall multidisciplinary management is strongly recommended.

In this guideline, **splinting** is the term used to describe the **process** of applying a prolonged stretch through the application of a range of devices. Most commonly, but not exclusively, a **splint** is made from thermoplastic material. In addition, prefabricated splints are sometimes used and are selected for or adapted to the individual. A **cast** is usually made from fibreglass casting tape or plaster of Paris; it is usually cylindrically applied and non-removable. However in certain instances casts may be bi-valved (cut in half) or made to be removable (Conine et al 1990). Both splints and casts can be serially adjusted to accommodate gains in range of movement. In addition, devices are available that are angle adjustable, which may also be useful in applying prolonged stretch. For clarity, the term

'orthoses' refers to all external devices, including splints and casts, but is commonly accepted in practice to mean devices provided by orthotists, usually for long-term management.

5. The occupational therapy and physiotherapy role

Occupational therapists and physiotherapists, as members of the wider health and social care team, play a key role in the management of long-term neurological conditions. As part of a comprehensive goal-directed rehabilitation or management programme, splinting can be a useful adjunct in the therapist's toolbox in the prevention and correction of contractures.

Both professions are committed to a person-centred and holistic philosophy. The core essence of the roles is described by their professional bodies as follows:

Occupational therapy is a unique philosophy that acknowledges the link between what people do and their health and wellbeing. To the profession 'occupation' means all the activities a person undertakes, enjoys and values. Occupational therapists are health and social care professionals who help people of all ages carry out activities they need or want to do, but as a result of physical or mental illness, disability or being socially excluded, are prevented from doing. (www.cot.co.uk)

Physiotherapy helps restore movement and function when someone is affected by injury, illness or disability. Physiotherapists help people affected by injury, illness or disability through movement and exercise, manual therapy, education and advice. At the core is the patient's involvement in their own care, through education, awareness, empowerment and participation in their treatment. (www.csp.org.uk/your-health/what-physiotherapy)

The decision to develop joint therapy guidance reflects the shared goal to enhance function which is integral to both professions.

6. Key steps for consideration when splinting adults with contractures

<p>Stage 1: Before considering splinting</p>	<ul style="list-style-type: none"> • Splinting should be regarded not in isolation but as one part of a comprehensive goal-directed rehabilitation or management programme (RCP 2009). • If relevant, remediable provocative factors for spasticity should be addressed first (e.g. pain, infection) (RCP 2009).
<p>Stage 2: Patient selection</p>	<ul style="list-style-type: none"> • Patients suitable for splinting are those who may have, or may be at risk of, contractures and other treatment strategies are not maintaining joint range of movement. • Goals of intervention should be identified (e.g. improving range of ankle-dorsiflexion or knee extension to enable standing or range of elbow extension to improve ease of dressing). • Splinting should not be considered in certain circumstances (ACPIN 1998, Delphi Consultation (Kilbride et al 2013), GDG Consensus), and caution is advised in others (see Boxes 6.1 and 6.2).
<p>Stage 3: Agree action plan with team</p>	<ul style="list-style-type: none"> • Identify specific splinting intervention to be applied – cast or splint, bespoke or 'off the shelf', design (e.g. consider pressure areas, lever lengths, materials used), patient position to optimise application, wearing regime. • Identify the appropriately skilled person(s) responsible for making/provision of the splint or cast (ISWP 2012, NICE 2013). • Agree monitoring regime. • Identify outcome evaluation, including timeframes.

Stage 4: Before splinting	<ul style="list-style-type: none"> • Provide appropriate information to patients and carers. See example form in Appendix 6 of the full guideline (COT 2015, p63). • Obtain informed consent. In cases where an adult is unable to consent, a consultee process may be applied with the next of kin following discussion with the team, including medical colleagues, and a best interests decision made (COT 2010, CSP 2012). • Record baseline measures.
Stage 5: Splinting procedure	<ul style="list-style-type: none"> • Make or provide splint or cast.
Stage 6: Documentation	<ul style="list-style-type: none"> • Document consent or consultation process (COT 2010, CSP 2012). • Document splint or cast application details. See example in Appendix 6 of the full guideline (COT 2015, p64). • Document splint or cast monitoring regime. See example in Appendix 6 of the full guideline (COT 2015, p65). • Provide personalised application and monitoring information to patient and carers. See example in Appendix 6 of the full guideline (COT 2015, p63).
Stage 7: Review	<ul style="list-style-type: none"> • Plan review dates and outcome evaluation (NICE 2013).

Box 6.1 Identified factors for caution when splinting

When splinting is being considered caution is advised:

- If the patient has a vascular disorder.
- If the patient has a concomitant fracture or severe soft tissue injury.
- If the patient is medically unstable.
- If the patient is incontinent.
- If the patient is diagnosed with heterotopic ossification.
- If the patient has acute inflammation.
- If the patient is unable to communicate.
- If the patient has cognitive or behavioural problems.
- If access to the limb is needed for medical procedures.
- If there is uncontrolled intracranial pressure.
- If there is poor skin integrity.
- If there is oedema.
- If there is sensory loss or hypersensitivity.
- If there is a fluctuating or severe tone or spasms.
- If there is a history of deep vein thrombosis.

(ACPIN 1998, Delphi Consultation (Kilbride et al 2013), GDG Consensus 2014)

Box 6.2 Factors to consider when splinting would not be advised

There was strong consensus in the Delphi Survey (2013) for when splinting would *not* be indicated:

- If there is no identified benefit.
- If it causes pain or discomfort.
- If there is no clear plan for application, removal or monitoring of the splint.
- If other treatment strategies are working.
- If there is poor patient compliance.
- If there is a lack of follow-up.
- If the contracture has become established resulting in fixed joint deformity. See Appendix 3 of the full guideline for more details (COT and ACPIN 2015, pp57-59).

7. Evidence references

- Abdolvahab M, Bagheri H, Mehdizadeh H, Oliaie G, Jalili M, Faghihzadeh S (2010) Effects of volar static splint on function and spasticity of upper extremity of hemiplegic adults. *Journal of Medical Council of Islamic Republic of Iran*, 28(1), 9–18.
- Amini M, Shamili A, Forough B, Kazemi R, Sayadinejad T, Taghizadeh Q (2009) Effects of volar-dorsal wrist/hand immobilization splint on range of motion, spasticity and function of affected upper extremity in stroke patients. *Modern Rehabilitation*, 3(3–4), 22–26.
- Basaran A, Emre U, Karadavut KI, Balbaloglu O, Bulmus N (2012) Hand splinting for poststroke spasticity: a randomized controlled trial. *Topics in Stroke Rehabilitation*, 19(4), 329–337.
- Beaty JA, Murphy AL (2013) Effectiveness of a flex orthotic splint on hand range of motion for older adults: a pilot study. *Physical and Occupational Therapy in Geriatrics*, 31(2), 159–167.
- Booth BJ, Doyle M, Montgomery J (1983) Serial casting for the management of spasticity in the head-injured adult. *Physical Therapy*, 63(12), 1960–1966.
- Bürge E, Kupper D, Finckh A, Ryerson S, Schnider A, Leemann B (2008) Neutral functional realignment orthosis prevents hand pain in patients with subacute stroke: a randomized trial. *Archives of Physical Medicine and Rehabilitation*, 89(10), 1857–1862.
- Carda S, Molteni F (2005) Taping versus electrical stimulation after botulinum toxin type A injection for wrist and finger spasticity: a case–control study. *Clinical Rehabilitation*, 19(6), 621–626.
- Carda S, Invernizzi M, Baricich A, Cisari C (2011) Casting, taping or stretching after botulinum toxin type A for spastic equinus foot: a single-blind randomized trial on adult stroke patients. *Clinical Rehabilitation*, 25(12), 1119–1127.
- Charait SE (1968) A comparison of volar and dorsal splinting of the hemiplegic hand. *American Journal of Occupational Therapy*, 22(4), 319–321.
- Conine TA, Sullivan T, Mackie T, Goodman M (1990) Effect of serial casting for the prevention of equinus in patients with acute head injury. *Archives of Physical Medicine and Rehabilitation*, 71(5), 310–312.
- Doucet BM, Mettler JA (2013) Effects of a dynamic progressive orthotic intervention for chronic hemiplegia: a case series. *Journal of Hand Therapy*, 26(2), 139–146.

- Farina S, Migliorini C, Gandolfi M, Bertolasi L, Casarotto M, Manganotti P, Fiaschi A, Smania N (2008) Combined effects of botulinum toxin and casting treatments on lower limb spasticity after stroke. *Functional Neurology*, 23(2), 87–91.
- Fayez E, Sayed H (2013) Influence of different types of hand splints on flexor spasticity in stroke patients. *Indian Journal of Physiotherapy and Occupational Therapy: an International Journal*, 7(1), 65–69.
- Grissom SP, Blanton S (2001) Treatment of upper motoneuron plantarflexion contractures by using an adjustable ankle-foot orthosis. *Archives for Physical Medicine and Rehabilitation*, 82(2), 270–273.
- Harvey L, de Jong I, Goehl G, Mardwedel S (2006) Twelve weeks of nightly stretch does not reduce thumb web-space contractures in people with a neurological condition: a randomised controlled trial. *Australian Journal of Physiotherapy*, 52(4), 251–258.
- Hill J (1994) The effects of casting on upper extremity motor disorders after brain injury. *American Journal of Occupational Therapy*, 48(3), 219–224.
- Jung YJ, Hong JH, Kwon HG, Song JC, Kim C, Park S, Kim Y, Ahn SH, Jang SH (2011) The effect of a stretching device on hand spasticity in chronic hemiparetic stroke patients. *NeuroRehabilitation*, 29(1), 53–59.
- Lai J, Jones M, Willis F (2008) Efficacy of dynamic splinting on plantar-flexion tone and contracture seen in CVA and TBI patients: a controlled, crossover study. In: *Proceedings of the 16th European Congress of Physical and Rehabilitation Medicine*, Turin, Italy. Turin, Italy: Edizioni Minerva Medica. 106–109.
Available at:
<http://www.dynasplint.com/uploads/3.%20Efficacy%20of%20DS%20on%20PF%20tone%20and%20Contracture.pdf>
Accessed on 14.01.15.
- Lannin NA, Horsley SA, Herbert R, McCluskey A, Cusick A (2003) Splinting the hand in the functional position after brain impairment: a randomized, controlled trial. *Archives of Physical Medicine and Rehabilitation*, 84(2), 297–302.
- Lannin NA, Cusick A, McCluskey A, Herbert RD (2007a) Effects of splinting on wrist contracture after stroke: a randomized controlled trial. *Stroke*, 38(1), 111–116.
- Lehmkuhl LD, Thoi LL, Baize C, Kelley CJ, Krawczyk L, Bontke CF (1990) Multimodality treatment of joint contractures in patients with severe brain injury: cost, effectiveness, and integration of therapies in the application of serial/inhibitive casts. *Journal of Head Trauma Rehabilitation*, 5(4), 23–42.
- Leung J, Harvey LA, Moseley AM, Tse C, Bryant J, Wyndham S, Barry S (2012) Electrical stimulation and splinting were not clearly more effective than splinting alone for contracture management after acquired brain injury: a randomised trial. *Journal of Physiotherapy*, 58(4), 231–240.
- Moseley AM (1993) The effect of a regimen of casting and prolonged stretching on passive ankle dorsiflexion in traumatic head-injured adults. *Physiotherapy Theory & Practice*, 9(4), 215–221.
- Moseley AM, Nicholson D, Riolo L, Wiggs L, Rothstein J (1997) The effect of casting combined with stretching on passive ankle dorsiflexion in adults with traumatic head injuries. *Physical Therapy*, 77(3), 240–259.
- Moseley AM, Hassett LM, Leung J, Clare JS, Herbert RD, Harvey LA (2008) Serial casting versus positioning for the treatment of elbow contractures in adults with traumatic brain injury: a randomized controlled trial. *Clinical Rehabilitation*, 22(5), 406–417.
- Pohl M, Rückriem S, Mehrholz J, Ritschel C, Strik H, Pause MR (2002) Effectiveness of serial casting in patients with severe cerebral spasticity: a comparison study. *Archives Physical Medicine and Rehabilitation*, 83(6), 784–790.

- Pohl M, Mehrholz J, Ruckriem S (2003) The influence of illness duration and level of consciousness on the treatment effect and complication rate of serial casting in patients with severe cerebral spasticity. *Clinical Rehabilitation* 17(4), 373–379.
- Robinson W, Smith R, Aung O, Ada L (2008) No difference between wearing a night splint and standing on a tilt table in preventing ankle contracture early after stroke: a randomised trial. *Australian Journal of Physiotherapy*, 54(1), 33–38.
- Shamila A, Amini M, Forough B, Kazemi R, Qorbani M (2011) Botulinum toxin injections or application of splints: impact on spasticity, range of motion and function of upper extremity in chronic stroke patients. *Iranian Journal of Pharmacology and Therapeutics*, 10(1), 11–16.
- Singer BJ, Jegasothy GM, Singer KP, Allison GT (2003a) Evaluation of serial casting to correct equinovarus deformity of the ankle after acquired brain injury in adults. *Archives of Physical Medicine and Rehabilitation*, 84(4), 483–491.
- Singer BJ, Singer KP, Allison GT (2003b) Evaluation of extensibility, passive torque and stretch reflex responses in triceps surae muscles following serial casting to correct spastic equinovarus deformity. *Brain Injury*, 17(4), 309–324.
- Verplancke D, Snape S, Salisbury CF, Jones PW, Ward AB (2005) A randomised controlled trial of botulinum toxin on lower limb spasticity following acute acquired severe brain injury. *Clinical Rehabilitation*, 19(2), 117–125.
- Yasar E, Tok F, Safaz I, Balaban B, Yilmaz B, Alaca R (2010) The efficacy of serial casting after botulinum toxin type A injection in improving equinovarus deformity in patients with chronic stroke. *Brain Injury*, 24(5), 736–739.

Supporting information references

- Ada L, Dorsch S, Canning CG (2006) Strengthening interventions increase strength and improve activity after stroke: a systematic review: 1. *Australian Journal of Physiotherapy*, 52(4), 241–248.
- Association of Chartered Physiotherapists in Neurology (1998) *Clinical practice guidelines on splinting adults with neurological dysfunction*. London: Chartered Society of Physiotherapy.
- Chartered Society of Physiotherapy (2012) *Quality assurance standards for physiotherapy service delivery*. London: CSP. Available at: <http://www.csp.org.uk/publications/quality-assurance-standards>
Accessed on 14.01.15.
- College of Occupational Therapists and Association of Chartered Physiotherapists in Neurology (2015) *Splinting for the prevention and correction of contractures in adults with neurological dysfunction: practice guideline for occupational therapists and physiotherapists*. London: COT.
- College of Occupational Therapists (2010) *Code of ethics and professional conduct*. London: COT. Available at: <http://www.cot.co.uk/sites/default/files/publications/public/Code-of-Ethics2010.pdf>
Accessed on 14.01.15.
- Conine TA, Sullivan T, Mackie T, Goodman M (1990) Effect of serial casting for the prevention of equinus in patients with acute head injury. *Archives of Physical Medicine and Rehabilitation*, 71(5), 310–312.
- Coppard B, Lohman H (2008) *Introduction to splinting: a clinical reasoning and problem solving approach*. 3rd ed. Edinburgh: Mosby Elsevier.
- Edwards S, Charlton P (2002) Splinting and the use of orthoses in the management of patients with neurological disorders. In: S Edwards, ed. *Neurological Physiotherapy*. 2nd ed. London: Churchill Livingstone. 219–253.

- Farmer SE, James M (2001) Contractures in orthopaedic and neurological conditions: a review of causes and treatment. *Disability and Rehabilitation*, 23(13), 549–558.
- GRADE Working Group (2004) Grading quality of evidence and strength of recommendations. London: *British Medical Journal*, 328(7454), 1490–1494.
- Guyatt GH, Oxman AD, Kunz R, Falck-Ytter Y, Vist GE, Liberati A, Schünemann HJ, Group GW (2008) Going from evidence to recommendations. *British Medical Journal*, 336(7652), 1049–1051.
- Halar E, Bell K (1988) Immobility. In: JD Lisa, B Gans, eds. *Rehabilitation medicine: principles and practice*. Philadelphia: Lippincott-Raven. 1015–1034.
- Intercollegiate Stroke Working Party (2012) *National clinical guideline for stroke*. London: Royal College of Physicians.
- Kilbride C, Hoffman K, Baird T, Tuckey J, Marston L, De Souza L (2013) Contemporary splinting practice in the UK for adults with neurological dysfunction: a cross-sectional survey. *International Journal of Therapy and Rehabilitation*, 20(11), 559–566.
- Kilbride C, Cassidy E (2011) Physical management of altered tone and movement. In: M Stokes, E Stacks, eds. *Physical management for neurological conditions*. 3rd ed. Edinburgh: Churchill Livingstone. 289–318.
- Lakie M, Robson LG (1988) Thixotropic changes in human muscle stiffness and the effects of fatigue. *Quarterly Journal of Experimental Physiology*, 73(4), 487–500.
- Lieber RL (2010) *Skeletal muscle structure, function, and plasticity: the physiological basis of rehabilitation*. London: Lippincott Williams & Wilkins.
- National Institute for Health and Care Excellence (2013) *Stroke rehabilitation: long-term rehabilitation after stroke*. Clinical Guideline 162. London: NICE. Available at: <http://www.nice.org.uk/guidance/cg162/resources/cg162-stroke-rehabilitation-full-guideline3>
Accessed on 14.01.15.
- Pandyan AD, Gregoric M, Barnes MP, Wood D, Van Wijck F, Burridge J, Hermens H, Johnson GR (2005) Spasticity: clinical perceptions, neurological realities and meaningful measurement. *Disability and Rehabilitation*, 27(1–2), 2–6.
- Pitts DG, O'Brien SP (2008) Splinting the hand to enhance motor control and brain plasticity. *Top Stroke Rehabilitation*, 15(5), 456–467.
- Rose G (1986) *Orthotics, principles and practice*. London: Heinemann.
- Royal College of Physicians (2009) *Spasticity in adults: management using botulinum toxin: national guidelines*. London: RCP.
- Vattanasilp W, Ada L, Crosbie J (2000) Contribution of thixotropy, spasticity, and contracture to ankle stiffness after stroke. *Journal of Neurology, Neurosurgery and Psychiatry*, 69(1), 34–39.