Splinting for the Prevention and Correction of Contractures in Adults with Neurological Dysfunction: *Practice Guideline for Occupational Therapists and Physiotherapists* (working title)

**College of Occupational Therapists**
*(Specialist Section Neurology Practice)*

**Chartered Society of Physiotherapy**
*(Association of Chartered Physiotherapists in Neurology)*
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Foreword
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The aim of this practice guideline is to provide specific recommendations to support best clinical practice and decision making in the provision of splints for adults with neurological conditions and who have contractures or are at risk of them developing. The recommendations are intended to be used alongside the therapist’s clinical expertise and, as such, the clinician is ultimately responsible for the interpretation of this evidence-based guideline in the context of their specific circumstance, environment and service users.

The recommendations should not be taken in isolation and must be considered in conjunction with the contextual information provided in this document and with the details on the strength and quality of the recommendations. It is strongly advised that the readers study section 5 together with the evidence tables in Appendix 7 (a&b) to understand the guideline methodology and to be aware of the outcome of the literature search, the Delphi Method survey (Appendix 3) and the overall available evidence.

Recommendations are scored according to strength, 1 (strong) or 2 (conditional), and graded from A (high) to D (very low) to indicate the quality of evidence. The 19 recommendation categories reflect the potential outcomes for therapists and service users when considering whether to provide/prescribe splints for adults with neurological conditions for the prevention and management of contractures and associated impairments.

SUMMARY TABLES OF RECOMMENDATIONS

<table>
<thead>
<tr>
<th>Lower Limb</th>
</tr>
</thead>
<tbody>
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<td><strong>Ankle: Contracture Correction:</strong></td>
</tr>
<tr>
<td>1. It is suggested that casting at maximum available range is used (for people with ABI and stroke) for improving range of movement at the ankle joint</td>
</tr>
<tr>
<td>Carda et al 2011 (B) stroke; Yasar et al 2010 (D) stroke; Verplancke et al 2005 (B) ABI; Singer et al 2003a ABI (C); Singer et al 2003b stroke &amp; ABI (B); Pohl et al 2002 (C) ABI &amp; stroke; Moseley et al 1997 (B) ABI; Moseley 1993 (C) ABI; Lehkmuhl et al 1990 (D) ABI, Booth et al 1983 (D) ABI.</td>
</tr>
<tr>
<td>2. It is recommended that ankle casting applied at maximal available range to improve joint range of movement be used in conjunction with botulinum toxin A (in people with stroke and ABI) when presenting with clinically significant spasticity. (See also RCP spasticity guidelines 2009)</td>
</tr>
<tr>
<td>Carda et al 2011 (B) stroke; Yasar et al 2010 (D) stroke; Farina et al 2008(B) stroke; Verplancke et al 2005 (B) ABI.</td>
</tr>
<tr>
<td>3. It is suggested that adjustable ankle splints applied at maximum available range can be used (in people with stroke and ABI) for improving joint range of movement.</td>
</tr>
<tr>
<td>Lai et al 2008 (C) ABI &amp; stroke; Grissom &amp; Blanton 2001 (D) stroke &amp; ABI.</td>
</tr>
</tbody>
</table>
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.  
Grissom & Blanton (2008) stroke & ABI (D)

### Ankle: Contracture Prevention

5. It is suggested that ankle casting at maximum dorsiflexion (in people with acute ABI) can prevent loss of range of movement  
Conine et al 1990 (C) ABI.

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  
Robinson et al 2008 stroke (B)

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.  
Robinson et al 2008 stroke (B)

### Knee: Contracture Correction

8. It is suggested that casting maybe used for the correction of contracture (in people with ABI and stroke) with the knee joint positioned at maximal available end range of movement  
Pohl et al 2002 (C) ABI & stroke; Lehkmuhl et al 1990 (D) ABI; Booth et al 1983 (D) ABI.

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)  
Pohl et al 2002, (C) ABI & stroke

### Knee: Contracture Prevention

10. It is suggested that casting at maximal available range of movement at the knee joint may be used (in people with stroke and ABI) for the prevention of contracture  
Pohl et al 2003 (C) stroke & ABI

11. It is suggested that caution is used when considering casting of more acute people (with ABI and stroke) and at lower levels of arousal because of possible risks of secondary complications (e.g. pressure areas)  
Pohl et al 2003 (C) stroke & ABI

### Upper Limb

### Hand & wrist: Contracture Correction

12. It is recommended that splints should be used in selected cases (not routinely) for the correction of range of movement (in people with stroke & ABI).  
Doutcet & Mettler 2013 (C) stroke; Feyez & Sayed 2013 (C) stroke; Abdolvahab et al 2010 (D) stroke; Amini et al 2009 (D) stroke; Shamila et al 2011 (D) stroke; Burge et al 2008 (A) stroke; Lannin et al 2003a (B) stroke & ABI; Beaty & Murphy 2013 (C) stroke; Charait 1968 (D) stroke, Leung et al 2013 (A) stroke and ABI; Lannin et al 2007 (A) stroke.
### Hand & Wrist: Contracture Prevention

13. It is recommended that splints should be used in selected cases **(not routinely)** to prevent loss in range of movement at the wrist and hand in (people with stroke and ABI).  
(Basaran et al 2012 (B) stroke; Shamila et al 2011 (D) stroke; Burge et al 2008 (A) stroke; Harvey et al 2006 (A) stroke & ABI; Lannin et al 2007 (A) stroke; Lannin et al 2003a (B) stroke & ABI)

14. It is suggested that splinting in conjunction with (in people with stroke & ABI) botulinum toxin A may reduce spasticity. as a component in preventing loss of range of movement in selected cases.  
Carda & Molteni 2005 (C) stroke & ABI.

15. It is suggested that electrical stimulation of wrist and finger muscles combined with a custom made wrist and hand splint should **not routinely** be applied to prevent the loss of range of movement (in people with stroke or ABI) and associated spasticity.  
Leung et al 2013 (A) stroke & ABI. The majority of splints were applied at maximal available range of movement, generally worn for 8 hours each day for 1-4 weeks.

16. It is recommended that a custom made wrist and hand splint should be used **(not routinely)** be applied to prevent the increase (or worsening) in spasticity (in people with stroke and ABI).  
Leung et al 2013 (A) stroke & ABI; Basaran et al 2012 (B) stroke; Jung et al 2011 (C) stroke; Shamila et al 2011 (D) stroke; Burge et al 2008 (A) stroke.

17. It is suggested that a splinting in a neutral wrist position may be beneficial (for people with stroke) for prevention of hand pain associated with joint malalignment.  
Burge et al 2008 (A) stroke.

### Elbow: Contracture Correction

18. It is suggested that casting at maximum available range is used (for people with ABI and stroke) for improving range of movement at the elbow joint.  
Moseley et al 2008 (B) ABI; Pohl et al 2002 (C) ABI & stroke; Hill 1993 (C) ABI; Lekmuhl et al 1990 (D) ABI;

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).  
Pohl et al 2002, (C) ABI & stroke
1 Introduction and definitions

This guideline has been developed to assist occupational therapists and physiotherapists with clinical decision-making when considering the provision of splints for contracture in adults with a neurological condition. As stroke, multiple sclerosis (MS) and acquired brain injury (ABI) accounts for 80% of the diagnostic categories of adults admitted to rehabilitation services in the UK (Barnes & Rademacher, 2003), these guidelines have been developed primarily drawing upon the literature from these clinical areas. In this guideline, the term **acquired brain injury** (ABI) encompasses non-stroke clinical presentations such as traumatic head injury (TBI), intracranial haemorrhage and arterio-venous malformation.

Contractures are a common complication of central nervous system damage and are thought to result from a combination of neural and non-neural factors, including spasticity and structural changes in soft tissues (Lieber 2010). **Contracture** is defined as a limitation in passive range of joint movement (Halar & Bell 1988). Contracture formation is complex, and a number of structures can be involved including the joint capsule, joint ligaments, muscles and tendons (Farmer & James 2001). **Spasticity** is defined by as a disordered sensori-motor control, resulting from an upper motor neurone lesion, presenting as intermittent or sustained involuntary activation of muscles (Pandyan et al, 2005). While the presence of spasticity does not mean the formation of contractures are inevitable, its presence in the overall clinical presentation can play a role in the development of non-neural and neural adaptations seen with decreasing range of movement (Hoang et al 2013; Ada et al 2006). 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 secondary complications (Pitts and O’Brien, 2008).

**Splinting** is a therapeutic intervention used by occupational therapists and physiotherapists in the management and prevention of contracture in adults with a neurological condition (Coppard & Lohman, 2007; Edwards & 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 p.7). The rationale underpinning splinting is to provide a prolonged stretch to promote change in a body structure (the theoretical basis of splinting is explored in more detail in Section 6). 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 this guideline, **splinting** will be the term used to describe the process of applying a prolonged stretch through the application of a range of devices made or provided by therapists. Most commonly a **splint** is made from a type of thermoplastic material, or a **cast** (made from ‘soft and scotch’ or plaster of Paris). Both these forms of splints, albeit more commonly with casts, can be serially adjusted to accommodate gains in range of movement. In addition, off the shelf splints are sometimes utilised and where possible adapted to the individual. For clarity and in keeping with common
practice, the term *orthoses* refers to external devices, which are specifically provided by orthotists (Charlton & Ferguson, 2008). Orthoses are not the focus of this guideline.

In the context of these guidelines, the aim of splinting is to correct and prevent contractures and in doing so facilitate improved function through increased range of movement. Using the International Classification of Functioning, Disability and Health (ICF) (World Health Organisation (WHO), 2001) as a theoretical framework, Figure 1.1 illustrates that while physiotherapists and occupational therapists may work at a body structure and function level (e.g. pain, range of movement), the primary aim is to always reduce activity limitations (e.g. increase independence in personal care or work), as well as reducing participation restrictions (e.g. having sufficient range of movement in the legs to sit in a car to visit family).

![Figure 1.1: Illustrating the bio-psychosocial of the splinting process within the ICF framework (WHO 2001)](image)

*Function* is defined as *active* or *passive*. *Active function* is when a functional task is performed by active movement of the individual’s affected limb e.g. to walk or using a fork to eat. *Passive function* is when a task such as cleaning the palm of the hand (hand hygiene) or the perineum is carried out on the affected limb by the individual using their unaffected (or less affected) limb or by someone else i.e. a carer.
Guidelines do not replace sound clinical reasoning and good clinical judgement. While the focus of this guideline is on splinting interventions that target the maintenance or increasing range of joint movement, this aim must be situated in the wider context and the needs of the individual person. Therapists must justify their actions based not only on the published evidence but also on their clinical experience and patient preference (Sackett et al, 1996). Context is also a key consideration, and splinting should not be undertaken in isolation; it is one part of a comprehensive goal directed rehabilitation or management programme (RCP 2009; ACPIN 1998). Given that both physiotherapists and occupational therapists have a shared overall aim in the management and treatment of contractures of improving and preserving function (Kilbride et al 2013), the decision to develop joint therapy guidance was taken.

1.1 Clinical context

There are an estimated eight million people in the United Kingdom (UK) with a neurological condition (The Neurological Alliance 2003). Resultant impairments such as contractures and spasticity can be seen in neurological conditions like stroke, MS and TBI (Fergusson et al 2007; van Kuijk et al 2007).

The incidence of contractures in people with neurological conditions in the UK is largely unknown. The global occurrence of contractures in neurological conditions in the published literature also varies widely. For example, 11% to 84% of people with TBI develop contractures (Yarkony 1987, Moseley et al, 2008), whereas those with hemiplegia or severe stroke, the reported incidence ranges from 43% (Sackley et al, 2008) to 100% (Malhotra et al, 2011). Studies undertaken in Australia report half of all adults admitted to hospital with stroke develop at least one contracture (Kwah et al, 2012a), whereas in a cohort of 156 participants with MS, over half had contracture in at least one major joint of the upper or lower limb; the most common site was the ankle (43.9%) (Hoang et al, 2013).

Attempts to identify clinical factors to predict who will develop contractures is complicated and complex as it is dependent upon the interaction of many factors (Diong et al 2012; Kwah et al 2012b). The sequence of events in contracture formation is not known and is likely to vary between different diagnoses (Harvey et al 2011). The documented time course for contracture formation is wide; from within 2 weeks of stroke (Ada et al, 2006), and appear to largely stabilise by 32 weeks (Pandyan et al, 2003). In stroke, contracture is most frequently predicted by weakness (Kwah et al, 2012; Pandyan et al, 2003) and reduced motor function (Kwah et al, 2012; Malhotra et al, 2011), and linked with increased stroke severity (Kwah et al, 2012). It is not predicted by degree of spasticity or pain (Kwah et al, 2012). While the presence of spasticity and contractures is not synonymous, and for some people spasticity positively helps function i.e. using the increased tone for transfers, for others their shared presence can play a role in the development of contractures (Ada et al, 2006). The minimisation of negative effects of secondary complications, like contractures, remains a key aim of rehabilitation (Cheeran et al, 2009).
While splinting is common as a part of treatment and management in neurological practice (Edwards and Charlton, 2002; Coppard and Lohman, 2007), the effectiveness of splinting as a stretch intervention for contractures remains the subject of on-going clinical debate (Katalinic et al, 2010, Lannin and Ada, 2011, Kilbride et al 2013). While the debate over the efficacy of splinting remains alongside the call for more research, splinting continues to be used in clinical practice and therapists need direction in dealing with this area of clinical uncertainty (Adrienne and Manigandan, 2011; Andringa et al 2013).

1.2 Context of service delivery

Adults with a neurological condition access health and social care in different settings and stages of their recovery or condition. This may include hyper acute stroke units, community rehabilitation teams, nursing or residential homes and within their own homes. As part of the overall agenda for improved management of long-term conditions (DH 2005), splinting can have a part to play in enhancing or maintaining an individual’s level of occupational performance i.e., engagement in activity and participation in society. Equally important is that therapists working across health and social care give due consideration to the social determinants of health as described in the Marmot Review (Marmot 2010). While this report is based on English data, the key message is relevant across the home countries, the access and equity of health should not be determined by social factors such as wealth, employment and housing.

The financial burden of contracture prevention and management, where documented, is considerable. In the absence of more up to date figures, the treatment cost for one contracture was estimated at £10,000 where inpatient treatment and surgery was required (Wade, 1991). The conservative prevention and management of contractures, where appropriate, is therefore advocated. National guidance recommends where people are at risk of losing joint range that specific treatment modalities such as casts and splints should be considered (NICE 2003; Intercollegiate Stroke Working Party 2012; National Institute for Health and Care Excellence, 2013). The estimated cost of splinting varies depending on the type and design. For example, a pre-fabricated positional splint maybe in the region of £90.00 plus VAT, whereas a custom made device would be more expensive given the cost of staff time to fabricate the device as well as the cost of the material.

1.3 The occupational therapy and physiotherapy role

Occupational therapists and physiotherapists, as part 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, management and treatment of contractures.

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

College of Occupational Therapy (2013). http://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.”


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

1.4 Practice requirement for the guideline

The practice requirement for this guideline is supported by a national online survey of members from the College of Occupational Therapists- Specialist Section Neurological Practice (COTSS-NP) and Association of Chartered Physiotherapists in Neurology (ACPIN), a professional network of the Chartered Society of Physiotherapy (CSP) (Kilbride et al 2013). Four hundred and twenty therapists completed the survey, of which the majority of responses indicated the need for practice guidelines. The last guidelines in this clinical area were produced by ACPIN in 1998 and these have since been withdrawn from circulation (ACPIN 1998).

Given the multifaceted nature of splinting as a complex intervention, multiple factors and many questions remain about practice. For example, the review of the evidence shows little is known about the dosage (wearing regime), with further variation across the upper and lower limbs, in addition to which muscle/s are involved (see evidence tables in Appendix 7a). These practice guidelines aim to provide therapists with direction in dealing with clinical uncertainty (Adrienne and Manigandan, 2011; Andringa et al 2013), and in identifying when to splint and equally importantly when not to splint.

1.5 Topic identification process

Practice guidance for splinting in neurology, as a guideline topic, was jointly identified by COTSS-NP and ACPIN. A decision was made to focus the guideline on the
treatment and management of contractures in adults with neurological dysfunction as it was the most commonly cited reason for splinting by the members of the professional networks.

A joint proposal to produce an OT and PT practice guideline for splinting in neurology was developed by COTSS-NP and ACPIN. The CSP Good Practice Panel and the COT Practice Publications Group subsequently approved this in January 2012.

1.6 Conflicts of interest

All guideline development group members (core group and co-opted), stakeholders and external peer reviewers were asked to declare any pecuniary or non-pecuniary conflict of interest, in line with the guideline development procedures (COT 2011a).

Declarations were made as follows (to be added to):

- Membership of the COTSS-NP and ACPIN professional networks by five members of the core guideline development group
- Dr Cherry Kilbride is a Senior Lecturer at Brunel University and a member of the core guideline development group. She stepped down from the latter group while the decision was being taken as to who would undertake the contract to lead the development of the guidelines.
- Tess Baird was Stroke Forum Chair of COTSS-NP at the time of the development of the joint proposal.
- Karen Hoffman teaches upper limb splinting courses for Harrison Training
- Jo Tuckey teaches splinting courses
- External peer reviewers and stakeholders identified were asked their membership of professional organisations.
- Professor De Souza was involved in the development of the ACPIN Splinting Guidelines (1998)
- Dr Stephen Ashford is a Consultant and Investigator on the Upper Limb International Spasticity (ULS) programme; a project evaluating focal spasticity intervention (physical and pharmacological) in the arm using botulinum toxin A and Chief Investigator for an NIHR clinical leadership award investigating focal spasticity intervention for leg spasticity (physical and pharmacological)

The nature of the involvement in all declarations made above was not determined as being a risk to the transparency or impartiality of the guideline development.
2 Objective of the guideline

The guideline objective:

To promote best practice in the use of splinting in adults with neurological dysfunction for the prevention, management and treatment of contractures

It is intended that occupational therapists and physiotherapists use this practice guideline to inform their work with service users, with a particular focus on empowering the service user to be as fully engaged in the self-management of their long-term neurological condition. Furthermore the guideline can be used as a resource with other end users, for example therapists and healthcare students.

The guideline should be used in conjunction with the current versions of the following professional practice requirements, of which knowledge and adherence is assumed:

- Standards of conduct, performance and ethics (Health and Care Professions Council (HCPC) 2012)
- Standards of proficiency – occupational therapists (HCPC 2012)
- Code of Ethics and Professional Conduct (COT 2010)
- Professional standards for occupational therapy practice, (COT 2011)
- Standards of proficiency – physiotherapists (HCPC 2013)
- Quality assurance standards for physiotherapy service delivery (CSP 2013)
- Code of members’ professional values and behavior (CSP 2011)
- Working for Health Equity (University College London Institute of Health Equity 2013)

As guidance rarely produces definitive answers (Scalzitti, 2001), is intended that this guideline be used alongside the therapist’s clinical expertise and, as such, the clinician is ultimately responsible for the interpretation of the evidence-based recommendations in the context of their specific circumstances and the service user’s individual needs and preferences.
3 Guideline scope

3.1 Clinical question

The key question covered by this guideline is:

*What is the evidence for the use of splinting in adults with neurological dysfunction for the prevention and correction of contractures?*

Implicit within this question is the recognition that service users are particularly concerned with functional outcomes, active or passive, and wider participation in society. However, to achieve these aims with a framework of a bio-psychosocial model of disability (WHO 2001), changes and maintenance in body structures and functions are required, and as such are addressed in this guideline.

3.2 Target population

People with stroke, MS and ABI accounts for 80% of the diagnostic categories of adults admitted to rehabilitation services in the UK (Barnes & Rademacher, 2003).

This practice guideline relates to adults 18 years and over, who have or at risk of contracture primarily as a consequence of stroke, ABI or MS and requiring splinting as one part of a comprehensive goal directed neurological rehabilitation or management programme.

3.3 Target audience

This practice guideline will largely be relevant to occupational therapists and physiotherapists working in the field of adult neurology across the full spectrum of health and social care settings from hyper-acute units in acute hospital trusts to nursing or care homes in the community and peoples own homes.

In addition to occupational therapists and physiotherapists, it is suggested that this practice guideline may also be relevant for:

- Other members of the multidisciplinary team e.g. Orthotists, Rehabilitation Medicine Physicians, Nurses
- Service users
- Managers responsible for purchasing splinting equipment
- Pre and post graduate university tutors
- Commissioners and service providers
- Charitable organisations such as the Stroke Association, Headway, MS Trust, MS society
- Student therapists
- Researchers
- Health and community and social care settings (except schools)

It is intended that the practice guideline provides a comprehensive, practical resource for occupational therapists, physiotherapists and the multi-disciplinary team working with adults with a neurological health condition who have or at risk of contracture.
4 Guideline development process

Detailed information on the following steps within the guideline development process can be found in the *Practice guidelines development manual* (COT 2011a).

4.1 The guideline development group

The membership of the core guideline development group (see Appendix 1 for a full list) comprised of two occupational therapists and two physiotherapists with extensive experience in adult neurology and expertise in splinting. It was determined that given the specific therapy nature of the practice guideline, the core group would be profession specific, with any expertise required from other stakeholders and service users most effectively obtained outside of core group meetings, via a reference group and consultation.

This was a funded project (see section 4.5) but much of the guideline development work was undertaken in private time, with additional support from external agencies such as the professional bodies and employers to attend meetings. In addition, the guideline development group co-opted three people for the following specific activities:

- Professor Lorraine DeSouza to provide professorial research and editorial advice
- Fabienne Malaprade to undertake semi-structured interviews with service users to gain insight on the experience of using splints
- Dr Amir Moghagheghi to undertake a specialist literature review on the pathophysiology of contracture

4.2 Stakeholder involvement

The primary aim of these guidelines is to provide guidance to therapists undertaking splinting as one part of a comprehensive goal directed rehabilitation or management programme. As the key end users, therapists have been involved in all stages of the guideline development process. Firstly, a national survey of neurological occupational therapists and physiotherapists (n=420) was undertaken as part of the initial scoping exercise (Kilbride et al 2013). The main items identified in the survey as important to therapists were: clinical reasoning, evidence based guidelines and wearing times and regimes. Secondly, an overview of the proposed scope of the guidelines was presented at the ACPIN and COTSS-NP respective national conferences to provide further opportunity for end user comment. Feedback was reviewed and where indicated incorporated into the final scope document which was then submitted to the College of Occupational Therapists Practice Publications Group and the Chartered Society Good Practice panel for approval. Next, over 200 therapists from across the UK were involved during the development of the guidelines by taking part in 3 rounds of a formal Delphi Consensus process. This is described in more detail in Section 8 and Appendix 3.

In addition to members of ACPIN and COTSS-NP, other key stakeholders with a
potential interest in the guideline were identified by the core group membership at an early guideline meeting. Specific attention was given to identifying national charity and voluntary organisations that may represent service users and professional colleagues who may be working as part of the multidisciplinary team, and included:

- The Stroke Association
- The MS Society
- Therapists in MS
- Headway
- Different Strokes
- British Association of Prosthetists and Orthotists

A targeted approach was used to seek views on the full draft guideline from professional bodies, national charities and clinical experts. All comments were duly considered for inclusion within the final guideline document.

4.3 Service user involvement

The guideline development group identified that obtaining service user perspectives on splinting for the management and treatment of contractures was fundamental to the project. There is a paucity of research into user experience on splinting (Andriga et al, 2013; Kuipers et al 2009). Recent studies, conducted in the Netherlands (Andriga et al, 2013) and another in the USA (Beatty and Murphy, 2013) explored user experience in stroke but concluded more qualitative in-depth exploration was required. To this end, and following ethical approval by the School of Health Sciences and Social Care Research Committee Brunel University London (reference number: 13/10/STF/03), a purposive sample of ten participants were recruited through local support and charitable organisations to take part in the interviews: 3 men and 2 women with stroke, 2 men and 1 woman with ABI, 1 man with MS. Following consent, 2 carers were also involved in the interviews at the request of the respective participants. This qualitative evidence was used to provide contextual support in section 8 Further Considerations for Practice. Appendix 4 contains more details on the service user involvement process.

4.4 External peer review and consultation

The guideline development group identified two independent peer reviewers to review a draft of the full guideline document. Reviewers were selected for their clinical expertise in the field, and/or their guideline development experience or knowledge. A one month consultation period was established to enable members of the COTSS-NP and CSP ACPIN members (guideline end users) to comment on a draft of the full guideline.

The guideline development group considered the feedback received from all stakeholders, service users, peer reviewers and end users, when forming the final recommendations and guideline document.
4.5 Declaration of funding for the guideline development

The practice guideline, *Splinting for the prevention and correction of contracture in adults with a neurological condition* (working title) has been developed by a group led by COTSS-NP and ACPIN. Specialist Sections and Professional Networks such as COTSS-NP and ACPIN are official branches of the College and Chartered Society with specialist or regional interests, who, through their membership, are able to engage expert practitioners, educators and researchers in the development of guidelines, and access the required clinical and research expertise. As a membership organisation the major source of funding for the College of Occupational Therapists and its Specialist Sections and the Chartered Society of Physiotherapy and its Professional Networks is obtained from membership respectively. Other sources of income are primarily from advertising and events. Joint funding was received from COTSS-NP and ACPIN and contracts of work to be undertaken were drawn up with Brunel University London, which enabled protected time for the academic team members to undertake work such as the specialist literature review, the critical appraisal of the literature and the Delphi survey. There were no external sources of funding.

4.6 College and Chartered Society appraisal and ratification process

The guideline proposal, scope and final document were all reviewed and subsequently ratified by the College of Occupational Therapists’ Practice Publications Group, and the Chartered Society of Physiotherapy Good Practice panel in line with the requirements of the Practice guidelines development manual (COT 2011a).

The final version of this guideline was approved by the College Practice Publications Group and CSP Good Practice panel in xxxx.
5 Guideline methodology

5.1 Guideline question

What is the evidence for the use of splinting in adults with neurological dysfunction for the prevention and correction of contractures?

The PICO (participant/population/problem, intervention, comparison and outcome) framework was used to assist in developing the specific practice question further.

This approach clarifies the specific care group or condition being studied, and the nature of the intervention to be investigated. A comparative treatment, can be defined where applicable, together with the anticipated outcomes (the desired/undesired or expected results of the intervention). This level of specificity is important in developing the question so that it addresses the requirements of the scope (COT 2011a).

Participant (service user), Population or Problem:
- Adults, 18 years and over who have or at risk of contracture as a consequence of stroke, acquired brain injury or multiple sclerosis.

Intervention under investigation or action:
- Splinting for the prevention or correction of contractures

Comparison, which is an alternative intervention or action
- Usual therapy practice (which may include no intervention)

Outcome desired:
- Range of movement as a specific outcome of this intervention, as one component of achieving functional activity and participation goals

5.2 Literature search methodology

A member of the guideline development group carried out the literature searches in conjunction with the College of Occupational Therapists and Chartered Society of Physiotherapy librarian information specialists, using a search strategy defined following discussion and agreement amongst the with the guideline development group.

The clinical and academic experience of the guideline development group meant there was prior knowledge that the therapy specific evidence related to splinting was likely to be limited. An initial scope of the literature and review of a Cochrane review (Katalinic et al 2010) indicated a limited number of randomised controlled trials (RCTs) of the interventions; this is not usual in rehabilitation research. Consequently the review was not confined to RCTs and all study designs that included the evaluation of splinting as a stretch intervention were included. Restricting the design to RCTs may have led to the exclusion of studies of interest and relevance to practice. On the basis of this the search covered a wide remit to ensure that there was adequate sensitivity to include all relevant articles.
5.2.1 Key terms and inclusion and exclusion criteria

The strategy involved combining groups of key words. Four key categories or concepts and their related terms were identified: splinting/casting/orthotics, physiotherapy, occupational therapy, neurology (stroke, multiple sclerosis, head/brain injury) (Appendix 5). Terms were adapted to the specific requirements of each database. There were no language restrictions and no time limits; databases were searched from inception of databases to April 2013. Reference lists included in full text papers were hand searched for additional relevant texts.

Inclusion and exclusion criteria of papers:

- Adult (18 years and over)
  - Diagnosis of stroke, multiple sclerosis or brain/head injury
  - Splinting for contracture management (prevention or correction) is primary focus of intervention
  - Primary outcome: range of movement

- Exclusion:
  - Case studies
  - Papers with <50% adults or target health conditions
  - Splinting for primary aim of promoting exercise

5.2.2 Databases

The databases searched reflected the most likely sources of evidence for physiotherapy and occupational therapy and splinting for contracture management. Seven core databases were searched from their commencement period to the search date as detailed in Table 5.1. The literature searches were carried out on the 7th and 19th February 2012 at the Chartered Society of Physiotherapy and College of Occupational Therapists respectively. The searches were re-run on 23rd April 2013.

Table 5.1: Database searches

<table>
<thead>
<tr>
<th>Core databases</th>
<th>Period of search</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cinahl</td>
<td>1981 to 23.4.13</td>
</tr>
<tr>
<td>Medline</td>
<td>1966 to 23.4.13</td>
</tr>
<tr>
<td>Allied and Complementary Medicine (AMED)</td>
<td>1985 to 23.4.13</td>
</tr>
<tr>
<td>Physiotherapy Evidence Database (PEDro)</td>
<td>1929 to 23.4.13</td>
</tr>
<tr>
<td>PsycINFO</td>
<td>1872 to 23.4.13</td>
</tr>
<tr>
<td>Social Policy and Practice</td>
<td>1980 to 23.4.13</td>
</tr>
<tr>
<td>Health Management Information Consortium (HMIC)</td>
<td>1979 to 23.4.13</td>
</tr>
</tbody>
</table>

Specialist databases were also searched: College of Occupational Therapists specialist library catalogue; Chartered Society of Physiotherapy Online library catalogue; OTDBASE; OT Search; OTSeeker; National Institute for Health and Care Clinical Excellence; Cochrane Library; NHS Evidence; DORIS (Database of Research in Stroke); Hooked on Evidence and the internet search engine Google Scholar.
In the majority of cases, title, subject heading and abstracts were searched. Where the search term combinations were more general, some limitations were then applied to provide a stronger focus on relevance. Examples of specific searches are detailed in Appendix 5.

5.3 Search results

The search findings identified a total of 1076 papers. These were scrutinised for duplicates by the guideline development group project lead (CK) both within database searches and cross-database search returns. As a result 532 papers were excluded. The remaining 554 papers were screened by two members of the project group (CK and SA) against an eligibility checklist previously discussed and agreed with the wider guideline development group.

Following screening, 479 papers were excluded identifying 65 papers for full review and critical appraisal. A search update a year later identified an additional 18 papers of which 11 were included. One paper was Korean and could not be translated and therefore a total of 7 papers were excluded. An overview of the literature search outcomes is provided in Figure 5.1.

A total of 76 articles were included in the final critical appraisal.

5.4 Strengths and limitations of body of evidence

Two members of the guideline development group independently reviewed the 76 articles identified as potential evidence. In the event of any discrepancy in grading, a third reviewer would be called upon; this was not required.

The quality of the evidence was initially assessed using the Critical Appraisal Skills Programme (CASP) checklists (CASP 2010). Assessment took into account factors such as the appropriateness of the study design and the recruitment strategy; procedural rigour in data collection and analysis; confounding factors and potential biases; transferability; precision of results and the value of the findings.

A grade was then also assigned to the evidence within an individual article using the GRADE approach as defined within the Practice Guidelines Development Manual (COT 2011a). The grading reflects the research design and the confidence in the research findings.

The initial grading was allocated as follows:

- Randomised trial/Systematic review = High
- Observational study = Low
- Any other evidence = Very low
Limitations in the design of a study or its implementation may, however, bias the estimates of the treatment effect. If there were serious limitations, then the downgrading of the quality of the evidence was considered, using the criteria shown in Table 5.2.

A decision to increase or decrease the initial grade of the evidence was justified in the evidence table. The ‘moderate’ category came into play if there was a suggested change in the grading. Evidence was ultimately graded in one of four categories, as detailed in Table 5.3. If there was no reason to up or downgrade the evidence, then the original grading remained.

Once the methodological quality of each piece of evidence was assessed, details for each item of evidence was collated into an evidence-based review table (Appendix 7a).

Table 5.2: Grading evidence up or down (after GRADE Working Group 2004)

<table>
<thead>
<tr>
<th>Decrease* grade if</th>
<th>Increase grade if</th>
</tr>
</thead>
<tbody>
<tr>
<td>* Each quality criteria can reduce the quality by one or, if very serious, by two levels</td>
<td>. Magnitude of the treatment effect is very large and consistent</td>
</tr>
<tr>
<td>. Serious or very serious limitation to study quality</td>
<td>. Evidence of a large dose-response relation</td>
</tr>
<tr>
<td>. Important inconsistencies in results</td>
<td>. All plausible confounders/biases would have decreased the magnitude of an apparent treatment effect</td>
</tr>
<tr>
<td>. Some or major uncertainty about directness of the evidence</td>
<td>Only studies with no major threats to validity should be upgraded.</td>
</tr>
<tr>
<td>. Imprecise or sparse data (relatively few participants and/or events)</td>
<td></td>
</tr>
<tr>
<td>. High probability of reporting bias</td>
<td></td>
</tr>
</tbody>
</table>
Figure 5.1: Literature search results

- Total search results $n=1076$
- Preliminary cleansing
  - Exclude $n=532$
- Abstracts included $n=544$
  - Exclude $n=479$
- Screened against criteria
- Full articles included $n=65$
  - Exclude $n=43$
- Critical appraisal $n=76$
  - Evidence included $n=33$
  - Update search identified $n=18$
    - Exclude $n=7$
Table 5.3: GRADE quality of evidence grading (after GRADE Working Group 2004)

<table>
<thead>
<tr>
<th>Quality of evidence</th>
<th>Grading</th>
<th>Characteristics</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Grade A</td>
<td>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.</td>
<td>True effect lies close to that of the estimate of the effect. Further research is very unlikely to change confidence in the estimate of the effect.</td>
</tr>
<tr>
<td>Moderate</td>
<td>Grade B</td>
<td>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.</td>
<td>True effect likely to be close to the estimate of the effect but the possibility that there could be a substantial difference. Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.</td>
</tr>
<tr>
<td>Low</td>
<td>Grade C</td>
<td>Based on observational evidence, or from controlled trials with several very serious limitations.</td>
<td>True effect may be substantially different from the estimate of the effect. Further research is very likely to have an important impact on confidence in the estimate of the effect and is likely to change the estimate.</td>
</tr>
<tr>
<td>Very low</td>
<td>Grade D</td>
<td>Based on case studies or expert opinion</td>
<td>Any estimate of effect is very uncertain and may be far from the true effect.</td>
</tr>
</tbody>
</table>

5.5 Methods used to arrive at guideline recommendations

All five guideline development group (GDG) members reviewed the evidence tables generated from the literature review. The primary research question (section 3.1) was used to identify themes/interventions that were relevant in answering the question. Each GDG member contributed their expert views to the discussion to develop recommendation options.

Where a number of papers supported an outcome and subsequent recommendation, an overall quality of evidence rating was identified:

- Where the evidence outcomes pointed in different directions towards benefit and towards harm, the lowest quality of evidence determined the overall
quality of evidence.
- Where the outcomes pointed in the same direction towards either benefit or harm, then the highest quality of evidence was appropriate to recommend an intervention and determined the overall quality of evidence.
- In circumstances where the balance of benefits and downsides was uncertain, then the lowest grade of quality of evidence was assigned.

Strength of recommendation was the second element of the GRADE system applied using the College categories, strong or conditional, to reflect the strength (Table 5.4).

**Table 5.4: Strength of grade** (after Guyatt et al 2008)

<table>
<thead>
<tr>
<th>Strength</th>
<th>Grade</th>
<th>Benefits and risks</th>
<th>Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strong</td>
<td>1. ‘It is recommended …’</td>
<td>Benefits appear to outweigh the risks (or vice versa) for the majority of the target group</td>
<td>Most service users would want or should receive this course of intervention or action.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conditional</td>
<td>2. ‘It is suggested…’</td>
<td>Risks and benefits are more closely balanced, or there is uncertainty in likely service user values and preferences</td>
<td>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.</td>
</tr>
</tbody>
</table>

The development of the recommendations, including assignment of the overall quality and strength grading, was a consensus opinion obtained at the guideline development group meeting. There were no recommendations which were not agreed by all members so that no formal voting system or nominal group session was required. Thirty three papers were used to develop the recommendations (see evidence tables in Appendix 7a).

A recommendation decision form was completed for each recommendation developed, recording key information about the evidence used to form the basis of that recommendation, the overall allocation of quality of evidence and strength of recommendation (recommendation decision forms are available on request from the College of Occupational Therapists). The recommendation decision form facilitated discussion and recording of any specific or associated risks and benefits, and this was also highlighted in the final strength of recommendation. Any judgement by the GDG was documented as part of this decision-making process.
5.6 Limitations and any potential bias of the guideline

Evidence included in the development of the guideline recommendations was sourced from published, peer reviewed journal articles. Relevant policy documents have been referenced within the contextual information where applicable. It is acknowledged that any potential key grey literature was not included.

The literature search identified a range of primary research in relation to the occupational therapy and physiotherapy studies involving splinting interventions for the management and treatment of contracture.

The review of the literature identified 33 items of evidence from which recommendations could be developed. The 33 studies were from a variety of countries. Australia (10) and the USA (8) lead the way, followed by Italy (3), Iran (3), Germany (2), and Turkey (2), Canada (1), Egypt (1), Korea (1), Switzerland (1) and the UK (1).

The majority of this evidence was assessed as low grade, followed by moderate level evidence and a small number of high level studies. Study designs were varied and included RCTs, controlled studies, cross over trials, case series and cohort designs amongst others. Although eight identified systematic reviews of evidence were critically appraised as part of the overall assessment of the literature (see evidence tables in Appendix 7b), they were not used to in the final process of formulating the recommendations, findings being used as a comparator with of guideline review results with those from the original studies.

Grade A = 12% (4)  
Grade B = 28% (9)  
Grade C = 36% (12)  
Grade D = 24% (8)

The evidence did, however, provide a number of higher quality studies from a design and methodological perspective. The guideline group downgraded over half (n =19, 58%) of the studies (A and C grade studies) concerns in the confidence of the estimate of the effect of the research. These decisions are noted in the evidence tables in Appendix 7a.

A potential limitation of this guideline is that in a number of cases, a recommendation has been developed on the basis of evidence, sometimes a single study, and often of a low grade. Future emerging evidence will be reviewed to determine any impact it may have on the nature of the recommendations within this practice guideline. The recommendation for a multi-centre randomised controlled trial of splinting for the prevention and correction of contractures in adults with neurology is evident.
The involvement of the College and the Specialist Section and the CSP and ACPIN in the development, authoring and funding of this practice guideline is fully acknowledged. This is a reflection of the organisational structure and the relationship between the professional bodies and its members. It should also be recognised that the practice area covered by the guideline is specialist, and that there are a limited number of experts within the field.

The potential for any bias in development and authoring was however minimised through the rigorous nature of the guideline development. This was achieved through the systematic methodology adopted, the contributions of stakeholders and service users, and the valued opinions of the independent peer reviewers and occupational therapy and physiotherapy end use
6 Examining the theoretical basis for splinting in contracture management.

6.1 Introduction

This chapter critically examines the theory base underpinning the potential use of splinting for contracture management in adults with neurological dysfunction. Studies primarily draw upon animal models, and evidence from studies involving human participants, which indicate the potential for increasing the number of sarcomeres in humans (Boakes et al, 2007; Theis et al 2013). Although plastic changes in muscle tendon units1 (MTUs) in response to long term stretching (splinting) can happen in the absence of normal muscle innervation i.e. (Williams & Goldspink 1976; Dupont Salter et al 2003) most studies involved healthy animals and humans, and generalisation of the results to muscle and tendon in different pathological conditions with different aetiologies should be done with caution. It remains unclear if a human MTU responds similarly to animal muscles due to anatomical differences between the species (Heslinga et al 1995) and altered structural and material properties of the muscles and tendons in pathological conditions (Boakes et al 2007; Zhao et al 1985; Mohagheghi et al 2007; Barber et al 2012).

Restriction in range of movement can lead to changes in soft tissue structures i.e. shortening and increased stiffness within the MTU, the joint capsule and ligaments (Lannin & Ada 2011; Herbert & Balmave 1993; Herbert & Crosbie 1997; Farmer & James 2001). Overall MTU length can alter with changes in the length of its various constituent components e.g. muscle, muscle fibres, sarcomeres, and tendon. While it is difficult to ascertain in the practice setting which component of the MTU has become shortened in response to being immobilised, it is nonetheless important that therapists consider this factor to deepen their understanding of the clinical picture when considering if lengthening via splinting can halt or reverse the adaptations.

The assumed benefits of splinting for contracture management are based on the potential effects of long-term and continuous stretch on the non-neural (i.e. the MTU) and neural mechanisms (including spasticity) involved in their development. The chapter is divided into these two areas, each section providing an overview of the key evidence.

6.2 Overview of non-neural mechanisms relevant to splinting

In healthy animals and humans, how muscles and tendons adapt to length change is complex. Variations are seen across different muscle groups (Williams & Goldspink 1971; Tabary et al 1972; Spector et al 1982; Heslinga et al 1995; Williams & Goldspink 1971), different species (Coutinho et al 2004; Comes et al 2004), ages (Williams & Goldspink 1973; Williams 1988; Williams & Goldspink 1978; Williams & Goldspink 1971; Crawford 1973; Urso et al 2006) and changes can be reversible

1 A muscle and its tendon that connects it to the skeleton are collectively called a muscle-tendon unit (MTU). Muscle and tendon can be considered as separate components of the MTU.
6.2.1 Adaptation of MTU properties in shortened positions

MTUs maintained in a shortened position can show an overall decrease in length and increased stiffness. A decrease in MTU length may happen due to a number of reasons:

- A decrease in the number of sarcomeres (Williams & Goldspink 1973; Williams 1988; Williams & Goldspink 1978; Tabary et al 1972; Spector et al 1982; Heslinga 1995)
- A decrease in the length of the sarcomeres (Spector et al 1982)
- A decrease in the length of muscle fibres (Tabary et al 1972; Spector et al 1982; Williams & Goldspink 1971)
- A decrease in the length of tendons (Herbert & Balnave 1993; Herbert & Crosbie 1997)

These factors, along with an increase in accumulation of connective tissue (Williams & Goldspink 1984; Williams & Goldspink 1973; Williams 1988; Jarvinen et al 2002), can all contribute to greater stiffness within the muscle, with a subsequent increased resistance to stretch. Tendon stiffness may be reduced (Couppe et al 2012; de Boer et al 2007) and thus not have sufficient resistance to counteract any increase in the muscle stiffness. This overall increase in the stiffness of the MTU however may be a contributing factor in the development of contractures (Lannin & Ada 2011; Herbert & Balnave 1993; Herbert & Crosbie 1997; Farmer & James 2001).

Muscle atrophy (Herbert & Crosbie 1997; Spector et al 1982; Heslinga et al 1995; Goldspink 1977) and a shift in the length-tension relationship of the MTU (Williams & Goldspink 1978; Tabary et al 1972; Crawford 1973) may also be observed. This means maximum muscle tension is less, and is produced at shorter lengths, and transferred to the skeleton with a longer electromechanical delay with less efficiency (Couppe et al 2012; de Boer et al 2007; Narici & Maganaris 2007; Reeves et al 2003), thus further compromising the performance of the MTU.

6.2.2 Adaptation of MTU properties to lengthened positions

Maintenance of MTUs at longer lengths i.e. with splinting may result in:

- An increase the number of sarcomeres (Williams & Goldspink 1973; Williams 1988; Williams & Goldspink 1978; Tabary et al 1972; Spector et al 1982; Heslinga et al 1995; Boakes et al 2007)
- An increase in the length of the muscle fibre (Spector et al 1982; Williams & Goldspink 1971; Boakes et al 2007)
- An increase in the length of the tendon (Williams 1988; Crawford 1973)
- Normal length-tension relationship and MTU stiffness may be preserved (Williams & Goldspink 1978; Tabary et al 1972)
- Accumulation of connective tissue within the muscle may be prevented (Williams & Goldspink 1984; Williams & Goldspink 1973; Williams 1988)

Electromechanical delay refers to the time interval between start of muscle activity and initiation of movement. Its duration is partially affected by the time required for stretching series elastic components amongst others.
• Increased stiffness of the MTU, however could still happen (Herbert & Balnave 1993) but muscle atrophy may be reduced (Herbert & Balnave 1993; Spector et al 1982; Goldspink 1977)

6.2.3. Clinical application

Decreased ankle ROM in stroke survivors has been associated with reduced gastrocnemius fascicle length and higher fascicular and muscle stiffness (Gao et al 2009). This supports the relationship between altered muscle architecture and the clinical symptoms of muscle stiffness and contracture. While this correlation cannot infer a cause and effect phenomenon, an increase in fascicular length with increased muscle length might be expected following an increase in the overall ROM of the ankle (along with the potential for improvement in passive or active function).

Serial casting, as an intervention to provide long-term stretch, might increase the overall ROM but an increase in fascicle and muscle length from serial casting has not been reported. This could be partly explained by an increased compliance of the tendon (reduced Young’s modulus3) after stroke or immobilisation (Zhao et al 1985), where a tendon may stretch relatively more than the muscle element of the MTU during and hinder potential benefits of stretching on the muscle component.

In children with spastic diplegic CP, Theis et al (2013) reported an increase in the medial gastrocnemius muscle, fascicles, and tendon lengths with short duration stretching in one treatment session. This study provides the first in vivo evidence for the potential effectiveness of long term stretching and/or splinting for inducing plastic changes in the muscle and tendon components of the MTU in this population.

The adaptations in MTUs described in this section may assist in improving overall MTU extensibility, thereby reducing the mechanical (non-neural) hypertonia component of contracture formation. However, stiffness of a MTU is relative to both its intrinsic mechanical properties and neural mechanisms, which controls its activation (Guissard & Duchateau 2004 & 2006; McHugh 1992). The neural mechanisms are reviewed in the context of splinting next.

6.3 Overview of neural mechanisms relevant to splinting

People with neurological dysfunction, including those with spasticity (neural hypertonia), may show increased resistance to elongation of the MTU. This has been attributed in part to the previously described alterations in the intrinsic properties of the MTU (Galiana et al 2005; Mirbagheri et al 2008; Li et al 2006), and to an increased gain in the stretch reflex4.

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3 Young’s modulus represents material properties of a tissue. It is defined as the change in the tissue stress for a given change in its strain. A tendon with lower Young’s modulus will be more compliant and would elongate more with respect to its original length for a given tensile force applied to its unit cross sectional area.

4 Here increased gain refers to both increased sensitivity and response to stretch.
6.3.1 Altered tone and contractures: spinal mechanisms

While the presence of spasticity (neural hypertonia) does not correlate with contractures, it does nevertheless for some people interfere with their range of movement, thus putting them at risk of contracture. Neural hypertonia has been identified as making a significant contribution to the increased resistance felt during passive stretching (Li et al 2006). An increase in stretch reflex gain which is associated with neural hypertonia can be attributed to a number of complex factors at a spinal level including the following:

- An increase in motor neuron (MN) pool excitability (Priori et al 2006),
- The inappropriate recruitment of the MNs (Mirbagheri et al 2008)
- An increase in muscle spindle activity (Li et al 2006; Gracies 2005)
- Reduced presynaptic inhibition (Priori et al 2006)

Factors such as these can lead to a reduced threshold of the tonic stretch activity in spastic muscles, i.e. when the stretch reflex is triggered in response to low stretching velocities which does not result in reflex activity in relaxed healthy muscles (Calota et al 2008; Pisano et al 2000).

Therefore, a theoretical construct for splinting in the presence of neural hypertonia is based on the potential efficacy of prolonged stretching of the MTU in modifying pre and post-synaptic mechanisms that affect the stretch reflex. In practice, interventions that are part of an overall goal directed rehabilitation or management programme, and can help to down regulate the stretch reflex (i.e. alter the reflex gain), could be helpful in reducing spasticity. This in turn, may help improve function in some people (active or passive) and/or the ease of care through the maintenance or improvement of range of movement.

6.3.2 Exploring the potential modifying effects of stretch on spinal mechanisms via splinting

Drawing upon animal and human models, there is theoretical and empirical evidence to support the potential use of stretch (splinting) as a way to modify neural mechanisms contributing to increased resistance to stretch.

Williams (1980) used an animal model and immobilised rat-tail muscles in either a shortened or lengthened position for 4 days. Results showed that muscle spindles in muscles immobilised in shortened positions became active in response to stretch at shorter lengths in comparison to spindles in muscles immobilised at longer lengths, which became active at extreme muscle lengths. Moreover, spindles in the muscles immobilised in the shortened position had a heightened response to the rate of stretch but those immobilised at long lengths had significantly lowered acceleration sensitivity. Williams concluded that changes in the mechanics of the intrafusal muscle fibres and the sensitivity of the receptors in the muscle spindles were responsible for the findings. Gracies (2005) argued the same mechanisms might be involved in the increased sensitivity of spastic muscles to stretch in the human model. In other
words, increased muscle spindle activity could help to explain abnormal velocity and length dependent resistance of the MTU to stretch in spastic muscles. In spastic muscles, an overall increase in the stiffness of the MTU (e.g. associated with increased amount of connective tissue, and reduced number of sarcomeres in the muscle held in a shortened position) could result in muscle spindles experiencing more of the stretching force. This happens when the stretching force is not being dissipated while taking up the slack in the muscles and tendon before stretching the intrafusal muscle fibres. Splinting (stretching) may therefore have the potential to interfere with the above mechanisms i.e. addressing the non-neural components described in the previous section which in turn will have an effect on the neural mechanism that can modify spasticity.

Furthermore, it has been demonstrated in healthy individuals that passive static stretching (10 min stretching per day for 30 days over 6 weeks) of the MTU can reduce the Hoffman (H) reflex,\(^5\) and tendon reflexes (Guissard & Duchateau 2004) and this has been associated with increased presynaptic inhibition of sensory signals (Guissard et al 2001, and thus reduced sensitivity to stretch. However, different pre and postsynaptic spinal mechanisms might be involved in the inhibition of reflexes (reduction of the MN excitability and/or excitation) at different magnitudes of stretch. For example, presynaptic inhibition might be involved in reducing MN excitability at small magnitudes of stretching (i.e. ankle dorsiflexion of 10 degrees), but golgi tendon organs (GTO) 1b afferents, Renshaw recurrent loops (Renshaw cells are inhibitory interneurons in the spinal cord), and alteration in supraspinal inter-neuronal circuitry were proposed by Guissard et al (2001) as possible mechanisms involved with stretches of large magnitude (i.e. ankle dorsiflexion of 20 degrees or more). Moreover in healthy individuals, repetitive and prolonged passive stretching (dorsiflexing the ankle to 10 degrees repeatedly at 1.5 Hz frequency for 1 hour) could reduce large 1a afferent sensitivity and consequently the reflex sensitivity to stretch (Guissard et al 1988; Avela et al 1999).

Other mechanisms proposed for spastic hypertonia might also be affected via stretching (splinting). In both healthy and hemiplegic individuals continuous or intermittent pressure on the Achilles tendon (AT) applied via a transducer pressing the tendon resulted in a reduction in the size of the H reflex (Kukulka et al 1986; Leone & Kukulka 1988). Watkins (1999) claimed that pressing the AT could be similar to the activation of the GTOs in a spastic muscle undergoing prolonged slow stretching. A drop in the H reflex may be inferred from similar mechanisms during splinting. Mirbagheri et al (2008) showed that stretch reflex gain and the intrinsic MTU stiffness was position dependent in people with and without spasticity, and reflex gain decreased but intrinsic stiffness increased at longer lengths. Reduction in the reflex gain at positions of extreme dorsiflexion in this study was suggested to be related to the activation of group III/IV afferents\(^6\), which are preferentially activated at

\(^5\) A spinal reflex used to give an indication of the overall excitability of the MNs. A smaller H-reflex may indicate less sensitivity to stretch.

\(^6\) These are unmyelinated or small myelinated diameter fibres including nociceptors and thermoreceptors.
extreme muscle lengths.

However in all reviewed studies, reduction in the MN excitation and/or excitability in response to stretching of varied duration was short lived. It should be noted that spasticity in different UMNS might be of a different nature (Tsao & Mirbagheri 2007; Faist et al 1999) due to its cause and location of lesion, and hence observed responses to prolonged stretching might be different for different pathologies. Furthermore there are methodological inconsistencies in the use of stretching in healthy and patient populations, along with a wide variation in the dosage of stretch and how it was applied.

6.4 Summary of the potential effect of splinting on non-neural and neural mechanisms in the prevention and correction of contracture

In conclusion, the current literature offers a complex and at times conflicting picture about how different muscles and tendons adapt to (sustained) stretched lengths. In particular, the inconsistency in the working definitions of the stretch magnitude applied (i.e. length of the MTU at which stretch is applied plus the duration and frequency of stretch) is not consistent across studies and no clear interpretation can be made based on the results.

While the literature can in part provide theoretical evidence for the potential effects of splinting on the non-neural and neural mechanisms involved in the prevention and correction of contractures, the results of the different studies are inconsistent and short lived. With so much still unknown, there is a real need for high quality research to explore in-depth the who (e.g. age, pathology), the what (e.g. response to stretch across different muscles and or tendons), and how (e.g. dosage, intensity, joint position) of splinting for contracture management as one part of a comprehensive goal directed rehabilitation or management programme where the aim is to utilise gains or maintenance of range in function, passive or active (RCP 2009; ACPIN 1998).
7 Guideline recommendations

These guideline recommendations refer to the application of stretch by splinting for the prevention or correction of contracture in adults with a neurological condition by occupational therapists and physiotherapists. This is one part of a comprehensive goal directed rehabilitation or management programme. As such, alternative treatment and management options are not explicitly reviewed or discussed. However some adjunctive interventions related to splinting were necessarily considered during the process of reviewing the evidence.

The recommendations are organised in sections related to interventions for the arm and leg. In turn, these sections are separated into different areas by joint. It is important to remember when reading this section that improvement in range of movement rarely leads directly to functional (active or passive) improvements. Splinting can help address one of the symptoms of altered motor control i.e. contracture, but this must be done in conjunction with a wider rehabilitation and or management plan. As previously noted, spasticity does not mean the formation of contractures are inevitable, but it can play a role in the development of non-neural and neural adaptations seen with decreasing range of movement.

Recommendations are scored according to strength, 1 (strong) or 2 (conditional), and graded from A (high) to D (very low) to indicate the quality of the evidence (sections 5.4 and 5.5). Each statement starts with either “It is recommended” or “It is suggested”.

‘It is recommended…’ means most service users would want, or should receive, this course of intervention or action.

‘It is suggested…’ means the majority of the 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.

Additional details on individual studies (for example, on recruitment numbers and statistical significant p values, effect sizes) can be accessed in the evidence-based review tables (Appendix 7a).

Information provided within the brackets of each recommendation illustrates the clinical population the evidence was drawn from. Given the numerous gaps in the research literature, it is suggested that recommendations are considered with caution when applied to other conditions or presentations other than that from which the evidence is drawn.
7.1 Lower Limb Recommendations

Correction and prevention of contracture in the lower limb can be a key clinical aim in the overall management of people who have altered tone as a symptom of a neurological condition. This section looks at the evidence base for the prevention and correction of contractures in the lower limb and is subdivided by joint area for ease of reference. The mean age of participants in the 16 lower limb studies identified is 41 years, more men than women were included and the average study sample size was 34. Most people in the studies had an ABI.

7.1.1 Ankle

a) Contracture Correction

Ten studies were identified, ranging from moderate to very low evidence that used casting to improve range of movement at the ankle joint (Carda et al 2011; Yasar et al 2010; Verplancke et al 2005; Singer et al 2003a; Singer et al 2003b; Pohl et al 2002; Moseley et al 1997; Moseley 1993; Lehkmuhl et al 1990; Booth et al 1983).

The majority of the 339 participants in the studies were people with an ABI. Nine of ten studies were conducted in chronic patient populations (participants in the Verplancke et al 2005 were a median of 10 days post insult).

1. It is suggested that casting at maximum available range is used (for people with ABI and stroke) for improving range of movement at the ankle joint. 2C

Carda et al 2011 (B) stroke; Yasar et al 2010 (D) stroke; Verplancke et al 2005 (B) ABI; Singer et al 2003a ABI (C); Singer et al 2003b stroke & ABI (B); Pohl et al 2002 (C) ABI & stroke; Moseley et al 1997 (B) ABI; Moseley 1993 (C) ABI; Lehkmuhl et al 1990 (D) ABI, Booth et al 1983 (D) ABI.

Casts were changed as range improved every 5-7 days, for 2-12 weeks

Five studies of moderate to very low quality utilised botulinum toxin A in conjunction with casting (Carda et al 2011, Yasar et al 2010, Farina et al 2008, Verplancke et al 2005, Singer et al 2003b). The majority of studies were in a chronic patient population, 92 of the participants were people with stroke and 45 had ABI.

2. It is recommended that ankle casting applied at maximal available range to improve joint range of movement be used in conjunction with botulinum toxin A (in people with stroke and ABI) when presenting with clinically significant spasticity. (See also RCP spasticity guidelines 2009) 1B

Carda et al 2011 (B) stroke; Yasar et al 2010 (D) stroke; Farina et al 2008(B) stroke; Verplancke et al 2005 (B) ABI.

Casts were changed every 5-7 days and applied for between 2 and 12 weeks.
Two studies from the USA (Grissom & Blanton 2001; Lai et al 2008) utilised adjustable ankle splints to provide a prolonged stretch to increase range of movement at the ankle joint. There were a total of 59 participants between the two studies; most of the people had a diagnosis of stroke. The reported incidence of adverse events (redness of skin and blistering) was high (44%) in the study by Grissom and Blanton (2001), which used pre-fabricated splints, and splints were only removed for hygiene purposes. There were no reported adverse events in the Lai et al (2008) study, which used a custom fit splint overnight for 6-8 hours. Both types of splints were regularly adjusted to maintain stretch at maximum available range.

3. It is suggested that adjustable ankle splints applied at maximum available range can be used (in people with stroke and ABI) for improving joint range of movement.  

Lai et al 2008 (C) ABI & stroke; Grissom & Blanton 2001 (D) stroke & ABI. Splints were applied for two to twelve weeks and between 6 and 23 hours a day; splints were adjusted as range improved.

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.  

Grissom & Blanton (2008 ) stroke & ABI (D)

b) Contracture Prevention

Two studies were identified that investigated the use of splinting for the prevention of plantarflexion contracture at the ankle joint.

Conine et al (1990) examined the effect of serial casting for the prevention of contracture in a before and after trial of 10 people with an average age of 28 years within 14 days of acute head injury. All participants had a GCS of less than 10 on admission and passive dorsiflexion of 0° or less. Results indicated the procedure overall was safe (1 adverse event, a small pressure sore reported) and reasonably efficient in this carefully selected population.

5. It is suggested that ankle casting at maximum dorsiflexion (in people with acute ABI) can prevent loss of range of movement.  

Conine et al 1990 (C) ABI. Casts were changed as range improved every 5-7 days until patients were able to maintain plantar grade. The final cast was bivalved and worn for 18 hours a day as a resting splint.
Robinson et al (2008) carried out a randomised controlled trial to compare the effectiveness of a temporary night splint with prolonged standing on a tilt table to prevent loss of ankle movement early after stroke (n=30). Results suggest that night splinting in this cohort of people was as effective as the tilt table in maintaining range of movement. Compliance in the tilt table group was 87% and 73% in the splinting group. Two pressure sores were noted with the use of non-customised splints.

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 2B

Robinson et al 2008 stroke (B)
The wearing time was 10 hours over night for 2-5 weeks

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.

Robinson et al 2008 stroke (B) 2B

7.1.2 Knee

a) Contracture Correction

Three studies were identified that examined the use of casting to correct contracture at the knee (n=33) in people with ABI and stroke with a mean age of 30 years. Most people received their first cast a minimum of 6 weeks post-neurological insult. The studies, all retrospective case study design, were undertaken between 1983 and 2002, and graded as low or very low quality. They reported less adverse events with the use of shorter duration casts (1-4 days, 8.8%, compared to 29.3% 4-7 days). Changes in casting materials, which allow cast removal for inspection of the skin, may help to reduce the rate of complications.

8. It is suggested that casting maybe used for the correction of contracture (in people with ABI and stroke) with the knee joint positioned at maximal available end range of movement 2D.

Pohl et al 2002 (C) ABI & stroke; Lehkmuhl et al 1990 (D) ABI; Booth et al 1983 (D) ABI. Casts were changed as range improved every 5-7 days and applied for between 2-12 weeks
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)  

Pohl et al 2002, (C) ABI & stroke

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**b) Contracture Prevention**

Pohl et al (2003) was the only study identified to report on the use of casting to prevent loss in range of movement at the knee joint in people with ABI and stroke (n=68), with an average age of 45 years. This study used a retrospective case comparison design, which is graded as low quality. Findings suggest more caution is required in the use of casts in acute patients with lower arousal levels.

10. It is suggested that casting at maximal available range of movement at the knee joint may be used (in people with stroke and ABI) for the prevention of contracture.  

Pohl et al 2003 (C) stroke & ABI Casting was changed every 5-7 days and applied for between 2- 5 weeks.

11. It is suggested that caution is used when considering casting of more acute patients (with ABI and stroke) and at lower levels of arousal because of possible risks of secondary complications (e.g. pressure areas)  

Pohl et al 2003 (C) stroke & ABI
7.2 Upper limb recommendations

This section focuses on the recommendations for the correction and prevention of contractures in the upper limb. It is subdivided into two main sections: the wrist and hand and the elbow. The participants (n=511) in the 19 upper limb studies (2 studies included both upper and lower limbs) had a mean age of 53 years, more men than women were included and the average study sample size was 27. In contrast to the lower limb studies, the vast majority of study participants were people with stroke.

7.2.1 Wrist and hand

a) Contracture Correction

Eleven studies were identified, ranging from high to very low evidence that used splints to improve range of movement at the wrist and hand joints (Beaty & Murphy 2013; Doutcet & Mettler 2013; Feyez & Sayed 2013; Leung et al 2013; Shamila et al 2011; Abdolvahab et al 2010; Amini et al 2009; Burge et al 2008; Lannin et al 2007; Lannin et al 2003a; Charait 1968). The majority of the 264 participants in the studies were people with stroke. Four of the eleven studies were conducted in acute patient populations, six in a longer term chronic population, and one with a mixed sample. A wide variety of custom made and off the shelf splints were used including volar, dorsal, cone, finger spreader, hand mitt and cone. Wearing regimens, both times and joint position varied widely in the different studies.

12. It is recommended that splints should be used in selected cases (not routinely) for the correction of range of movement (in people with stroke & ABI). 1A

Doutcet & Mettler 2013 (C) stroke; Feyez & Sayed 2013 (C) stroke; Abdolvahab et al 2010 (D) stroke; Amini et al 2009 (D) stroke; Shamila et al 2011 (D) stroke; Burge et al 2008 (A) stroke; Lannin et al 2003a (B) stroke & ABI; Beaty & Murphy 2013 (C) stroke; Charait 1968 (D) stroke, Leung et al 2013 (A) stroke and ABI; Lannin et al 2007 (A) stroke.

Splints were custom made or serially adjustable (10° wrist extension and finger extension, wrist at neutral, or maximal available range of movement). The majority were worn for between 20 minutes and 12 hours, for between 1-8 weeks

No casting studies were identified.
b) Contracture Prevention

Six studies, graded from high to very low quality were identified that examined the use of splinting for the prevention of contracture in the hand and wrist (Basaran et al 2012; Shamila et al 2011; Burge et al 2008; Harvey et al 2006; Lannin et al 2007; Lannin et al 2003a). The majority of participants were people with stroke. Three of the studies were conducted in acute patient populations (Burge et al 2008; Lannin et al 2007; Lannin et al 2003a), and three in a longer term chronic population. No casting studies were identified. Wearing regimens, both times and joint position varied widely in the different studies.

13. It is recommended that splints should be used in selected cases (not routinely) to prevent loss in range of movement at the wrist and hand in (people with stroke and ABI).

1A

(Basaran et al 2012 (B) stroke; Shamila et al 2011 (D) stroke; Burge et al 2008 (A) stroke; Harvey et al 2006 (A) stroke & ABI; Lannin et al 2007 (A) stroke; Lannin et al 2003a (B) stroke & ABI)

Splints were applied in a variety of positions (10° wrist extension and fingers fully extended, wrist at neutral, or close to maximal available range of movement). Splints were generally applied between 6 and 12 hours each day, and from 1 to 8 weeks.

One case-control study by Carda & Molteni (2005) (n=65) used botulinum toxin A in conjunction with splinting to ameliorate symptoms of spasticity, an impairment which can impact on range of movement. This study used taping to apply a prolonged stretch at the end of available joint range. Most participants were more than 3 months post stroke.

14. It is suggested that splinting in conjunction with (in people with stroke & ABI) botulinum toxin A may reduce spasticity as a component in preventing loss of range of movement in selected cases.

2C

Carda & Molteni 2005 (C) stroke & ABI.

Splinting was carried out at end of available range but not adjusted daily. Strapping was applied at end of available range of movement, with daily adjustment to maximal stretch for 6 days.
An RCT (n=36) of high quality was identified that examined the use of electrical stimulation as an adjunct to splinting for the prevention of loss in range of movement and associated spasticity. The majority of participants (average age of 57 years), were 55 days post stroke. People with contracture that prevented finger extension with the wrist in neutral were excluded.

15. It is suggested that electrical stimulation of wrist and finger muscles combined with a custom made wrist and hand splint should not routinely be applied to prevent the loss of range of movement (in people with stroke or ABI) and associated spasticity. 2A

Leung et al 2013 (A) stroke & ABI. The majority of splints were applied at maximal available range of movement, generally worn for 8 hours each day for 1-4 weeks.

Five studies, graded from high to very low quality were identified that examined the use of splints in people with hand and wrist spasticity (Leung et al 2013; Basaran et al 2012; Jung et al 2011; Shamila et al 2011; Burge et al 2008). Splint designs, and wearing regimens, both times and joint positions, varied widely in the different studies.

16. It is recommended that a custom made wrist and hand splint should be used (not routinely) be applied to prevent the increase (or worsening) in spasticity (in people with stroke and ABI). 1A

Leung et al 2013 (A) stroke & ABI; Basaran et al 2012 (B) stroke; Jung et al 2011 (C) stroke; Shamila et al 2011 (D) stroke; Burge et al 2008 (A) stroke.

Splints were all custom made (10° wrist extension and fingers fully extended, wrist neutral, or just off maximal available range of movement). The majority of splints were worn for between 20 minutes and twelve hours each day, for 1-8 weeks.

One high level study, a RCT by Burge et al (2008) investigated the effect of a neutral alignment custom-made splint on range of movement, pain, oedema and mobility. All participants (n=31) were post stroke and had a mean age of 68 years.

17. It is suggested that a splinting in a neutral wrist position may be beneficial (for people with stroke) for prevention of hand pain associated with joint malalignment 2A.

Burge et al 2008 (A) stroke

The splint was worn for a minimum of 6 hours each day for up to 13 weeks.
7.2.2 Elbow

a) Contracture Correction

Four studies, graded from moderate to very low quality (Moseley et al 2008, Pohl et al 2002, Hill 1993, Lekmuhl et al 1990) investigating the use of casting for the correction of contracture in the elbow were identified. Most participants had an ABI, and were more than 6 weeks post insult. Less adverse events were reported with the use of shorter duration casts.

<table>
<thead>
<tr>
<th>18. It is suggested that casting at maximum available range is used (for people with ABI and stroke) for improving range of movement at the elbow joint. 2C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moseley et al 2008 (B) ABI; Pohl et al 2002 (C) ABI &amp; stroke; Hill 1993 (C) ABI; Lekmuhl et al 1990 (D) ABI;</td>
</tr>
<tr>
<td>Casts were changed as range improved every 3-7 days, for between 1-4 weeks.</td>
</tr>
</tbody>
</table>

No studies using splints were identified.

<table>
<thead>
<tr>
<th>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</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pohl et al 2002, (C) ABI &amp; stroke</td>
</tr>
</tbody>
</table>

Contracture Prevention

There were no studies identified that looked at the use of splinting in the prevention of contracture at the elbow.
8. Informing Clinical Practice: the clinician and user experience

8.1 Introduction

Numerous gaps were identified in the evidence during the literature review for these guidelines. Until more is known, therapists must think carefully about their clinical practice, and in keeping with the principles of evidence-based practice should justify their actions based upon a combination of the published evidence, their clinical experience and patient preference (Sackett et al 1996). This section combines current practice from experienced therapists and insights from listening to service users on the realities of splinting. Finally, as practice should be formally assessed and evaluated, suggestions for outcome measures are also presented from systematic review, other areas of the literature and expert opinion.

8.2 Experiential evidence from practice

Whilst in developing the resources in this section, the clinical experience of occupational therapists and physiotherapists across the UK were drawn upon through the use of the Delphi Method Survey (Black 2011) over a period of four months. The approach was purposively selected as the research tool of choice as it can help to achieve consensus in an area of uncertainty (see Appendix 3 for further details). The specific aim was to identify and gain consensus on factors that influence a clinician’s decision making on whether to instigate a splinting regimen as part of the overall approach to contracture management. In clinical areas where evidence was not available, consensus recommendations for practice are made based on the collective views and respective knowledge and experience of the GDG, and any other relevant documents i.e. national clinical guidelines where necessary.

The lack of consensus amongst therapists on key factors for splinting as a part of contracture management was perhaps not surprising given the multitude of biopsychosocial variables that can influence a personalised approach to therapy intervention. However there was strong consensus about when not to include splinting as a clinical intervention.

Table 8.1 and Figures 8.1 and 8.2 outlines considerations for and against splinting as part of a comprehensive goal directed treatment and management plan for contracture
### Table 8.1 Key steps for consideration when splinting adults with contractures

#### Stage 1: Before considering splinting
- Splinting should not be regarded 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)

#### Stage 2: Patient selection
- Patients suitable for splinting are those who may have or may be at risk of contractures and other treatment strategies are not maintaining range
- 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 (Delphi consultation 2013) and caution is advised in others (Delphi consultation 2013, ACPIN 1998, Guideline development group). (See Figures 8.1 and 8.2)

#### Stage 3: Agree action plan with team
- Identify the specific splinting intervention to be applied e.g.
  - Cast or splint
  - Bespoke or ‘off the shelf’
  - Design
  - Patient position to optimise application
  - Wearing regime
- Identify the appropriately skilled person(s) responsible for making/provision of the splint or cast (Intercollegiate Stroke Working Party 2012, NICE 2013)
- Agree monitoring regime
- Identify outcome evaluation including time frames

#### Stage 4: Prior to splinting
- Provide appropriate information to patients and carers (see example forms)
- 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 (CSP 2012, COT 2010)
- Record baseline measures

#### Stage 5: Splinting procedure
- Make or provide splint or cast

#### Stage 6: Documentation
- Document consent or consultation process (CSP 2012, COT 2010)
- Document splint or cast application details, see example in Appendix 6
- Document splint or cast monitoring regime, see example in Appendix 6
- Provide personalised application and monitoring information to patient and carers, see example

#### Stage 7: Review
- Plan review dates and outcome evaluation (NICE 2013)
Figure 8.1 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 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
- If there is fluctuating or severe tone

(Splinting guideline development group 2014, Delphi 2013 and ACPIN 1998)

Figure 8.2 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 is fixed

(See Appendix 3 for more details)
8.3 Key messages from service users summarised within the ICF framework

More detail of the service user involvement in the development of these guidelines can be found in section 4.3 and appendix 3. Key messages from service users and carers are grouped into positive and negative experiences under different ICF categories. These categories could assist therapists to consider user experience during goal setting as part of an overall rehabilitation or management programme.

8.3.1 Service user experience of impairments (body structure and function)

Overall patients described positive experiences in terms of improvement in impairment. This specifically related to improvement or maintenance in range of movement and reduction of spasticity.

‘Until the serial casting started, getting my left heel down was always a struggle (P4)
Without the splint ‘hand is shrivelled up into a ball (P2)
(the splint)…it takes the pain away from the wrist (P5)

However therapists are reminded that caution is required when adjusting splints to gain range as this can lead to adverse events:

….my wrist and hand swelled up when the splint was adjusted (P7)

8.3.2 Service user experience of activities and limitations

Participants described how activities could be made easier or harder with splinting. Some participants told of how using splints helped them to resume playing music:

Helps me to play the drums (P4)
Big brace I use for the piano (P9)

In contrast another service user reported on the downside of wearing splints, which whilst they provided a stretch to help maintain range in their hands, they were potentially made more reliant on others for personal tasks:

Once I’ve got them on…I can’t move, I can’t do anything…it’s actually stretching everything…not possible to use in bed as need to use urine bottle (P1)

Whereas the use of ankle splints, whilst helping to maintain range of movement, also provided stability for people when out and about:

My leg splint is vital to me…without this solid form; I will fall over (P3)

Nonetheless these benefits expressed by service users came at a price for some:

You virtually had to cut, sort of ruin a pair of shoes to get it on (P6)
…can’t wear nice shoes, having to buy two pairs, one pair bigger to get the splint in; its expensive and embarrassing, I wouldn’t want to take a splint to a shop (P9)

Service users also told of discomfort they experienced from splinting, especially
whilst trying to sleep

*Can’t turn over in bed, so I am lying on my back…wake up in absolute agony… (serial cast foot)* (P4)

*Sleeping at night is hindered by hand splint* (P8)

The importance of sleep is essential, given that fatigue affects many people during rehabilitation (Mead et al 2007) and beyond and the potential link to depression and anxiety when sleep is disturbed (ISWP 2012).

### 8.3.3. Service users experiences of participation and restrictions

Examples were provided by service users on how splints, in particular those for the lower limb helped them to participate more within their environment:

*When I travel it is a massive aid in my life* (P4)

*Helps with getting in and out of the car* (P7)

However they also told of some negative impacts of splinting on their lives:

*Holding hands with children…it’s [splint] quite bulky* (P3)

*People want to be able to go to formal occasions, they want to be able to wear a skirt or dress (wearing an ankle splint)…what do you do* (P8)

Insights from service users such as these provide powerful reminders of the wider impact of splinting on not just the individual but within wider society.

### 8.3.4 Service users experiences of environmental and personal factors

The ICF, as a bio-psychosocial framework, takes into consideration the dynamic interaction of the individual with their environment i.e. how features of their physical, social and attitudinal world can have an external influence on their and disability, whereas personal factors reflect internal influences. Devices used in splinting are classified within the product & technology category of the environmental factors.

The following excerpts from service users describe their experiences of the splinting process firstly from the perspective of the environment and then personal factors are briefly considered.

How a splint or cast looked was important to many of the service users but appearance was not everything

*It’s ugly…but it is doing the job* (P8)

In contrast other participants were conscious of wearing their splint in public:

…it’s ugly, it is ugly…I wasn’t wearing it out at all…(P7)

“…if I ever get out into the general public with them on…would not be a good look at all…it would put another label on me…” (P1)

Some service users explained they preferred their splint to have a ‘sporty’ look:
...this is more acceptable as could be for a sports injury... (P1)

...(this one) is sporty looking...put on a pair of shorts and you look like you have had a sports injury (P5);

Some service users commented upon the colour of the splinting material; white featured on a number of occasions but for a variety of reasons:

White is too medical (P8)

White is more neutral, draws less attention (P4)

...if it’s white or anything like that it gets grubby...(P6)

The weight of the splinting device also featured prominently in what service users said:

...we take breaks during the day as it (arm splint) is heavy (P3)

it gets heavy...it is not easy lugging it around (hand splint) (P7)

Given the potential long-term nature of wearing splints for some service users, it is important that services and systems are in place to monitor and adjust splints as required. People spoke of mixed experiences:

...suddenly out of the blue it started rubbing, rang up and offered appointment, very quick (P7)

...in hospital I was really skinny, when I got out I put on weight and the splint was too tight and had to stop wearing it … (P8)

...what is lacking is any kind of hospital aftercare…(P10)

Personal factors, which are described with the ICF as internal influences, are important to consider as part of the overall splinting process, especially given some of the challenges described by service users. Motivation to continue to wear splinting devices is a key internal resource, and varied depending on individual circumstances such as:

...having a goal of recovery, I just thought it was going to help (P8)

Whereas P3, who has extremely limited functional hand and arm use, described the role of his family in motivating him to continue using his splints:

“I’m very distressed by not being able to hold my wife. I think my family’s my greatest loss for me, and my greatest motivation.”

8.3.5 Summary

The importance of listening to the experience of service users is evident from the insights shared in this subsection as part of the guideline development process. It is now incumbent upon therapists to incorporate them into practice.
8. 4 Outcome Measurement Recommendations

All treatment interventions should have a formal assessment of outcome. It is suggested that outcome evaluation be considered when appropriate at three levels (Ashford and Turner-Stokes 2013):

1. Goal attainment: have the intended goals for treatment been achieved?
2. Body system structure and function: has splinting intervention produced an improvement or maintenance in range of movement?
3. Activity or function: Has this had any impact on function, either in terms of ‘passive’ (ease of care) or ‘active’ functional activity performed by the patient?

In some people it will be appropriate to consider whether the intervention has produced an improvement at the level of participation, well-being or quality of life for the individual and/or carer. Evidence of cost-effectiveness is becoming ever more important.

While agreeing the goals for treatment with the individual and their family, the treating team should consider which measures would be appropriate to assess outcome, and to ensure these are recorded at baseline and re-evaluated at defined intervals (see Table 8.1).

Systematic review findings for outcome evaluation

The measures applied in studies evaluating splinting intervention were identified from the systematic review of the literature (see section 7) and are presented in Table 8.1 below.

Table 8.1 Key measures identified in splinting evaluation studies

<table>
<thead>
<tr>
<th>Measure</th>
<th>Number of studies used</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lower Limb</strong></td>
<td>Total studies; N = 16</td>
</tr>
<tr>
<td>Range of movement</td>
<td>14</td>
</tr>
<tr>
<td>Modified Ashworth Scale (spasticity evaluation)</td>
<td>4</td>
</tr>
<tr>
<td>Functional Independence Measure</td>
<td>2</td>
</tr>
<tr>
<td>10 or 6 meter timed walk (LL motor control)</td>
<td>2</td>
</tr>
<tr>
<td><strong>Upper Limb</strong></td>
<td>Total studies; N = 19</td>
</tr>
<tr>
<td>Range of movement</td>
<td>16</td>
</tr>
<tr>
<td>Modified Ashworth Scale (spasticity evaluation)</td>
<td>8</td>
</tr>
<tr>
<td>Tardieu Scale (spasticity evaluation)</td>
<td>4</td>
</tr>
<tr>
<td>Fugl-Meyer Assessment (UL motor control)</td>
<td>4</td>
</tr>
<tr>
<td>Pain (visual analogue scale)</td>
<td>3</td>
</tr>
<tr>
<td>Motor Assessment Scale</td>
<td>3</td>
</tr>
<tr>
<td>Grip strength (dynamometer)</td>
<td>2</td>
</tr>
<tr>
<td>Patient Satisfaction</td>
<td>2</td>
</tr>
</tbody>
</table>

The measures applied for the upper and lower limb evaluation addressed aspects of body systems structure and function, with the exception of patient satisfaction. No evaluation of activity was undertaken, and participation, well-being and quality of life were not addressed. In addition, studies have not considered issues of cost effectiveness.

Outcome evaluation methods

In addition to the systematic review findings, recommendations have been made
using accepted or developing models of outcome evaluation in practice. Reference has also been made to systematic reviews and practice recommendations in other related areas of practice (Ashford et al. 2008; Royal College of Physicians et al. 2009; Ashford and Turner-Stokes 2013; Ashford et al. In press), as well as expert opinion in the guideline development group. The following model for outcome evaluation reflects this process and also includes suggestions for measurement tools that can be used in clinical practice and or research.

1. Have the treatment goals been achieved?
Clear goals for treatment should always be documented. Goals for intervention vary from patient to patient and a single outcome measure cannot necessarily capture all domains.

Goal Attainment Scaling (GAS) is one method to record the successful attainment of one or more goals that are important to the individual. First introduced in the 1960s by Kiresuk and Sherman (1968), this technique was found to be suitable for health problems which warrant a multidimensional and individualised approach to treatment planning and outcome evaluation (Kiresuk et al. 1994). It has been successfully used to demonstrate clinically important change in the context of focal spasticity management (Ashford and Turner-Stokes 2006; Ashford and Turner-Stokes 2008), in addition to other areas of rehabilitation practice (Khan et al. 2008; Wade 2009; Turner-Stokes et al. 2009a). Goal attainment is rated on a five-point scale and combined into a single score through the application of a standard formula.

Has the splinting intervention produced an improvement or maintenance in joint range of movement?
It is important to assess the change or maintenance in range of movement (ROM) at the relevant joint, because if splinting has not been effective at the level of body function, it is unlikely that any activity gains may be attributed to the intervention.

It may also be appropriate to apply a clinical measure of spasticity if spasticity is identified as a particular problem for the patient undergoing intervention e.g. modified Ashworth (Bohannon & Smith 1987), Tardieu (Gracies et al 2000) and modified Tardieu (Boyd & Graham 1999)

2. Impact on activity (active and passive function)
Importantly, identification of functional improvements of benefit to service users (and sometimes carers, formal and informal) should be assessed when appropriate. Standardised scales allow comparison between individuals and groups, therefore application of these tools maybe particularly useful if group or service evaluation is being considered.

Active function
Global measures, such as the Barthel Index or the Functional Independence Measure (FIM), are less likely to be sensitive to change arising from focal intervention such as splinting. Where patients have underlying selective voluntary movement in the limb, but contracture limits ‘active’ function (e.g. by preventing standing and walking due to inability to extend the knee), improvement in the contracture may lead to improved active function. Evaluating this type of
improvement, if it is anticipated will then be particularly important.

Possible measures of active function include:

**Upper limb:**

- Action Research Arm Test (ARAT) (Van der Lee et al. 2002; Koh et al. 2006)
- The Arm Activity measure – active function sub-scale (ArmA)* (Royal College of Physicians et al. 2009; Ashford et al. 2013b; Ashford et al. 2013c; Ashford et al. in press)

**Lower limb:**

- 10 meter walking time, or six minute walking distance**

*Patient Reported Outcome Measures (PROMs)

**Though not automatically activity, the relationship to mobility in an activity context is accepted

**Passive function**

In some cases, there may be little possibility of restoring active function, but improving the ease of caring for the affected limb, for example in washing and dressing, can make significant impact on quality of life and carer burden. This type of outcome may also have cost benefits in reducing the time taken to provide care, or the number of people required, to perform care tasks.

Possible measures of passive function include:

**Upper limb:**

- The Arm Activity measure – passive function sub-scale (ArmA)* (Ashford et al. 2013b; Ashford et al. 2013c; Ashford et al. in press).
- Visual analogue scales or numeric rating scales may also be used.

Verbal or visual analogue ratings of ‘ease of care’ or timed care tasks e.g. time taken for dressing/washing could also be used to evaluate this type of outcome.

**Lower limb:**

- The GDG are not aware of any standardised measures addressing these issues in the context of lower limb splinting.
- Visual analogue scales or numeric rating scales may be used to quantify improvements in this context.
9 Service user perspectives of the recommendations /guidelines

[This section should include information on the overall service user opinions and understanding of the recommendations. Quotes can be used to illustrate points made by service users]

Information should be divided and numbered as follows:

8.1

8.2

This will be completed following the consultation and peer review
10 Implementation of the guideline

This practice guideline aims to support occupational therapists and physiotherapists to provide specific recommendations to support the judicious and considered use of splinting as an intervention for the prevention and correction of contractures in adults with a neurological dysfunction.

Familiarisation with the guideline document will be an important first step for both the individual practitioners and their managers. It is, therefore, imperative that occupational therapists, physiotherapists and managers working in the area take responsibility to review the guideline recommendations within the context of their practice.

Bringing the guideline to the attention of colleagues in the multidisciplinary team, service commissioners and other relevant people should also be a priority.

A further action to facilitate implementation must be for lead therapists to consider the ‘levers’ and ‘barriers’ within their local organisation and culture that may have an impact on any changes that may be necessary to practice. Section 10.2 identifies some potential barriers that may be applicable, while section 10.3 provides details of resources to facilitate implementation.

10.1 Dissemination and promotion

To facilitate dissemination, the full practice guideline is available to download freely from the College of Occupational Therapist’s website and the Chartered Society of Physiotherapy ACPIN website.

Following publication in xxxx the guideline will also be promoted to its key target audience of occupational therapists, physiotherapists and to relevant others using professional networks and publications, Internet and social media channels.

10.2 Organisational and financial barriers

The recommendations stated within this guideline document are intended to facilitate occupational therapy and physiotherapy staff to provide an effective and considered splinting service as an adjunct intervention as part of a comprehensive goal directed approach to the prevention and correction of contractures in adults with a neurological condition.

It is recognised however that there will be potential barriers, both organisational and financial, which may influence application of the recommendations. It is important that occupational therapists and physiotherapists take these into account when implementing the guideline.

The recommendations are varied but potential issues impacting on implementation that may present across all recommendations include:
- The availability of appropriately trained occupational therapists and physiotherapists within the multidisciplinary team (MDT). The MDT would also ideally include orthotists and plaster technicians to support therapy colleagues in patient rehabilitation and care. Staffing resources will therefore be important in facilitating implementation. The following factors may impact on service provision:
  - Increased throughput of service users.
  - The introduction of a seven day service.
  - An ongoing climate of cost efficiencies.
  - The increasing number of people receiving treatment.
  - Different service settings including care at home or other community settings.
- Adequate provision of splinting equipment to undertake safe practice
- Support from managers and commissioners of services
- Financial support to provide a service.

### 10.3 Implementation resources

Three core implementation resources are available to support this practice guideline. All implementation resources can be downloaded, together with the full guideline document, from the COT publications section (Practice guidelines) of the College of Occupational Therapists' website and from the CSP ACPIN website resources section.

#### 10.3.1 Quick reference guide

The quick reference guide lists the recommendations and indicates their strength and the quality of the evidence leading to their development.

This is intended to be used by practitioners as an easily-accessible reminder of the recommendations for intervention. It should be ideally 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 content.

#### 10.3.2 Audit form

The audit form provides a template for individual occupational therapists and physiotherapists or services to audit and review their current interventions against the recommendations.

A baseline assessment conducted using the audit tool can be repeated to enable actions identified from the audit to be monitored.

The audit form, while initially providing a tool for use within an individual/service context, offers the potential for future benchmarking and wider comparative analysis.
10.3.3 Continuing professional development session

A set of PowerPoint slides and supporting documentation provides the resources for an individual or service to conduct a continuing professional development session focused on the practice guideline.

The learning outcomes for the session are:

- To explore aspects of the evidence-based guideline/recommendations in relation to current practice.
- To develop an understanding of the importance of using an evidence-based guideline to inform practice.
- To explore and develop an understanding of how to use the College of Occupational Therapists’ and Chartered Society of Physiotherapy ACPIN audit tool for the evidence-based recommendations.

The PowerPoint slide set can also be valuable in increasing awareness about the guideline, and additionally can be tailored to meet local needs.

A feedback form is also available to provide comment or updates to the College of Occupational Therapists and the Chartered Society of Physiotherapy (ACPIN).
11 Recommendations for future research

The review of the evidence has identified a lack of primary research in the UK and beyond on splinting in contracture management. Areas for future research include:

- Dosage/wearing times
- Identifying optimal methods of application
- Investigating the effects of splinting across different joints/muscles/conditions
- The use/choice and timing of outcome measures
- Multi centre studies i.e. RCTs
- Role of splinting in MS and contracture management
- Role of electrical stimulation and contractures
- Splinting and casting in combination with BTA and other therapy adjuncts
- Mechanisms research to understand more about what happens in the MTU
- Clinical decision making and thresholds for providing splinting
- More exploration of the user experience
- Service delivery models for follow up and review including more integration with orthotics services
- User informed design of devices
- Longitudinal studies on who develops difficulties with contractures/loss of movement.
12 Updating the guideline

The National Executive Committees of the College of Occupational Therapists Specialist Section – Neurology and the Association of Chartered Physiotherapists in Neurology are responsible for ensuring future review of this guideline, and will also provide a focal point for the respective professions for any feedback received on the guideline following its publication.

This guideline is scheduled for update by XXXX XXXX; however the review date may be brought forward if there is significant new evidence which may impact on practice.

Members of the respective National Executive Committees will be notified of any significant development in the evidence in the period prior to the review through dissemination on their respective websites, newsletter and journal distributions and an update on the evidence base presented at their annual conference.

The wider membership of the British Association of Occupational Therapists and Chartered Society of Physiotherapy will also be made aware of any significant developments via the respective publication OTnews or Frontline.

Information about the College of Occupational Therapists Specialist Section – Neurology is available at: http://www.cot.co.uk/cotss-neurology…

Information about the Association of Chartered Physiotherapists in Neurology is available at www.acpin.net
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- COTSS-NP member

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Co-opted members

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- Lecturer in Biomechanics, Brunel University London.

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[Details any other relevant contributors, stakeholders, service users, carers, peer reviewers etc]

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Heather Jane Young
Stakeholder to be further populated

British Association of Prosthetists and Orthotists

Headway

Stroke Association

Different Strokes

The MS Society

Therapists in MS
Appendix 3

Summary of the national Delphi Method survey
Ethical approval from Brunel University 13/10/STF/03

This section summarises the Delphi Method Survey (Black 2011) with occupational therapists and physiotherapists, which was carried out over a 4-month period, to explore factors influencing clinical decision making in the provision of splints for adults with neurological conditions that have contractures or are at risk of developing them. The specific aim was to identify and gain consensus on factors that influence clinician’s decision making as to whether to splint a patient or not, as part of the overall approach to contracture management.

The Delphi Method was selected as the research tool of choice as it can help achieve consensus in an area of uncertainty. Respondent knowledge drives decision making; it is quick, cheap and efficient and can cover a wide geographical area. It is conducted anonymously to other group members; individual members of a group express their views in private such that other members remain unaware of each person’s judgment. This provides an opportunity for people to rethink/change their initial views in light of seeing anonymised initial views of all group members. There is an explicit and transparent derivation of the group’s decision, based on pre-arranged statistical methods of aggregation and analysis. (Delphi method (BMJ book – Pope and Mays).

Overview of the study

The survey was undertaken via email and used SurveyMonkey as the platform to collect the data across 3 rounds. The aim was to recruit 100 OTs and 100 PTs who were HCPC registered, a minimum of Band 6 and able to splint without supervision in practice.

Round 1: Participants were asked to:

- List up to 5 key factors that informed their clinical decision TO splint
- List up to 5 key reasons that inform your clinical decision NOT to splint
- Provide a short explanation for each reason given in an accompanying free text box.

Thematic content data analysis was undertaken by CK, JT, KH, TB. 10% of data was initially coded independently and inter-judge agreement was calculated by an independent statistician using the kappa coefficient: reasons TO splint = .877 and NOT to splint .974. Both sets of results indicated a very high level of agreement.

Round 2:

- Findings from Round 1 were presented back to participants who were then asked to rank in order of personal priority/what they consider to be most important top 5 key factors to splint and not to splint.
Round 3:

- Participants are presented with the group rankings from Round 2 and asked to confirm or change priority of the group rankings.

An analysis of agreement (consensus) was calculated to determine the level of agreement (Kendall’s co-efficient of concordance) between therapists.

Results

The response rate was high across the 3 rounds. An average of 194 therapists (range 218-179) participated in each round.

Most therapists (n=172, 79%) were Band 7 or above with nearly 50% (n=104, 47.7%) having been qualified for 15 years or more. Most therapists (n=172, 78%) worked in an inpatient setting (acute n=70, 31%; rehabilitation n=102, 46.8%), followed by N=144 66% outpatients (31.7% n=69) and/or community (34.4%, n=75) (can work across settings so higher number):

Mostly employed by NHS (79.4%; n=173); Private (11.5%; n=25); Charity (6.9%; n=15); self employed (9.6% n=20)

Geographical spread from across the 4 home countries.

Dominated by London (n=88; 40.4%) and the SE (n=25, 11.5%); Scotland n=13 (6%)

NI n=2 (0.9%); Wales n=5 (2.3%)

<table>
<thead>
<tr>
<th>Key factors identified in R1 when TO splint</th>
<th>Group Ranking from R2</th>
<th>R3 Mean rank PT</th>
<th>R3 Mean rank OT</th>
<th>Joint</th>
</tr>
</thead>
<tbody>
<tr>
<td>To protect a joint</td>
<td>1</td>
<td>3.22</td>
<td>3.23</td>
<td>3.22</td>
</tr>
<tr>
<td>In the presence of increased tone</td>
<td>2</td>
<td>4.72</td>
<td>3.64</td>
<td>4.25</td>
</tr>
<tr>
<td>To improve joint alignment</td>
<td>3</td>
<td>4.21</td>
<td>4.59</td>
<td>4.37</td>
</tr>
<tr>
<td>To promote comfort &amp; manage pain</td>
<td>4</td>
<td>5.07</td>
<td>4.75</td>
<td>4.93</td>
</tr>
<tr>
<td>To increase range of movement</td>
<td>5</td>
<td>5.06</td>
<td>6.04</td>
<td>5.48</td>
</tr>
<tr>
<td>To enable active function</td>
<td>6</td>
<td>5.42</td>
<td>6.20</td>
<td>5.76</td>
</tr>
<tr>
<td>To promote personal hygiene &amp; skin integrity</td>
<td>7</td>
<td>6.17</td>
<td>5.81</td>
<td>6.01</td>
</tr>
<tr>
<td>An adjunct to anti-spasticity medication</td>
<td>8</td>
<td>6.19</td>
<td>5.65</td>
<td>5.96</td>
</tr>
<tr>
<td>To maintain or prevent</td>
<td>9</td>
<td>4.95</td>
<td>5.10</td>
<td>5.02</td>
</tr>
</tbody>
</table>

Kendall Co-efficient W test

OT TO splint: .150
PT TO splint: .114
Joint: .115
Factors to splint were very ‘bunched’ and so less discriminatory; **very poor consensus** demonstrated among therapists when considering factors TO splint in adults with a neurological condition with or at risk of contracture.

<table>
<thead>
<tr>
<th>Key factors identified in R1 when NOT to splint</th>
<th>Group ranking from R2</th>
<th>R3 Mean rank PT</th>
<th>R3 Mean rank OT</th>
<th>Joint</th>
</tr>
</thead>
<tbody>
<tr>
<td>No identified benefit</td>
<td>1</td>
<td>1.22</td>
<td>1.61</td>
<td>1.39</td>
</tr>
<tr>
<td>Pain or discomfort</td>
<td>2</td>
<td>2.22</td>
<td>2.25</td>
<td>2.23</td>
</tr>
<tr>
<td>Unable to apply, remove or monitor</td>
<td>3</td>
<td>3.50</td>
<td>3.84</td>
<td>3.65</td>
</tr>
<tr>
<td>Poor skin integrity</td>
<td>4</td>
<td>4.26</td>
<td>4.65</td>
<td>4.43</td>
</tr>
<tr>
<td>Other treatment strategies are working</td>
<td>5</td>
<td>5.91</td>
<td>5.57</td>
<td>5.76</td>
</tr>
<tr>
<td>Restrict activity/movement</td>
<td>6</td>
<td>6.90</td>
<td>6.02</td>
<td>6.52</td>
</tr>
<tr>
<td>Oedema</td>
<td>7</td>
<td>6.99</td>
<td>7.30</td>
<td>7.12</td>
</tr>
<tr>
<td>Poor patient compliance</td>
<td>8</td>
<td>8.12</td>
<td>7.98</td>
<td>8.05</td>
</tr>
<tr>
<td>Lack of follow up</td>
<td>9</td>
<td>8.73</td>
<td>8.66</td>
<td>8.70</td>
</tr>
<tr>
<td>Altered sensation</td>
<td>10</td>
<td>9.15</td>
<td>9.37</td>
<td>9.25</td>
</tr>
<tr>
<td>Fixed contracture</td>
<td>11</td>
<td>10.17</td>
<td>9.83</td>
<td>10.02</td>
</tr>
<tr>
<td>Fluctuating /severe tone</td>
<td>12</td>
<td>10.84</td>
<td>10.92</td>
<td>10.87</td>
</tr>
</tbody>
</table>

**Kendall Co-efficient W test**

OT NOT to splint: **.71**

PT Not to splint : **.755**

Joint: **.732**

Factors not to splint were discriminating consistently; **high consensus** demonstrated among therapists when considering factors NOT to splint in adults with a neurological condition with or at risk of contracture.
Appendix 4: Service user consultation
(Ethics approval reference number 13/10/STF/03- Brunel University London)

An integral part of developing evidence-based guidelines for splinting is the involvement of users and carers who know what it is like to use splints and casts as part of rehabilitation and everyday life. Knowledge about user experience can help improve collaboration between users and professionals, which has been noted to be key to the implementation and development of successful interventions (Radomski, 2011). However there is a paucity of research into user experience on splinting (Andriga et al, 2013; Kuipers et al 2009). Recent studies, conducted in the Netherlands (Andriga et al, 2013) and another in the USA (Beaty and Murphy, 2013) explored user experience in stroke but concluded more qualitative in-depth exploration was required. To this end a purposive sample of ten people and 2 carers participated in semi-structured interviews to explore the lived experience of splinting for the management and or prevention of contractures in people with neurological conditions. Data from participants with carer involvement was treated as a dyad i.e. analysed as a pair. Participants were recruited from local support and charitable organisations and participant characteristics are shown in Table A4.1 Inclusion and exclusion criteria were:

**Inclusion criteria:**
- Adults 18 years and over with a diagnosis of Stroke or MS or TBI
- Have experience of wearing a splint in the last year as part of treatment and management of those people at risk (or with) contracture as a result of their neurological condition

**Exclusion criteria:**
- Unable to give informed consent
- Unable to speak conversational English (if English is not their 1st language and money is not available for translation services)

**Table A4.1: Participants characteristics**

<table>
<thead>
<tr>
<th>ID</th>
<th>Gender</th>
<th>Neurological insult</th>
<th>Age range</th>
<th>Time post insult</th>
<th>Joint area/s</th>
<th>Customised or off the shelf splint</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>Male</td>
<td>MS</td>
<td>50-59</td>
<td>14 years</td>
<td>Wrist &amp; hand</td>
<td>Both</td>
</tr>
<tr>
<td>P2</td>
<td>Male</td>
<td>Stroke</td>
<td>30-39</td>
<td>4 years</td>
<td>Wrist &amp; hand, ankle</td>
<td>Both</td>
</tr>
<tr>
<td>P3</td>
<td>Male</td>
<td>TBI</td>
<td>40-49</td>
<td>3 years</td>
<td>Elbow, wrist &amp; hand, knee &amp; ankle</td>
<td>Both</td>
</tr>
<tr>
<td>P4</td>
<td>Male</td>
<td>TBI</td>
<td>30-39</td>
<td>7 years</td>
<td>Wrist &amp; hand, ankle</td>
<td>Both</td>
</tr>
<tr>
<td>P5</td>
<td>Male</td>
<td>Stroke</td>
<td>30-39</td>
<td>9 months</td>
<td>Wrist &amp; hand, ankle</td>
<td>Both</td>
</tr>
<tr>
<td>P6</td>
<td>Female</td>
<td>Stroke</td>
<td>60-69</td>
<td>10 years</td>
<td>Wrist &amp; hand, ankle</td>
<td>Both</td>
</tr>
<tr>
<td>P7</td>
<td>Female</td>
<td>Stroke</td>
<td>30-39</td>
<td>4 years</td>
<td>Shoulder &amp; elbow, ankle</td>
<td>Both</td>
</tr>
<tr>
<td>P8</td>
<td>Female</td>
<td>Stroke</td>
<td>40-49</td>
<td>1.5 years</td>
<td>Wrist &amp; hand, ankle</td>
<td>Both</td>
</tr>
<tr>
<td>P9</td>
<td>Female</td>
<td>TBI</td>
<td>40-49</td>
<td>8 years</td>
<td>Wrist &amp; hand, ankle</td>
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<td>Stroke</td>
<td>40-49</td>
<td>2 years</td>
<td>Wrist &amp; hand, ankle</td>
<td>Both</td>
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<td>ID</td>
<td>Gender</td>
<td>Relationship to Participant</td>
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<td>C3</td>
<td>Male</td>
<td>Paid Carer</td>
<td>20-29</td>
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<tr>
<td>C10</td>
<td>Female</td>
<td>Wife</td>
<td>40-49</td>
<td>N/A</td>
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The indicative guide for interviews included the previous or current use of splint/cast, comfort, specific design of the splint including style, fit, colour, and acceptability. Self-reported difficulties with their limb was also explored to place the use or non-use of the splint/cast in context with perceived limitations including muscle tightness (i.e. spasticity), skin hygiene, comfort, pain, oedema, use of the arm or leg in function e.g. using arm in activities of daily living and/or transferring in/out bed, chairs, standing and walking.

All data were transcribed verbatim, and transcriptions were checked against the original recordings. Data were analysed using an analysis framework (Ritchie & Spencer 2003). Another member of the research team independently reviewed the process of coding, first theme identification and the development of the overarching themes, supporting the rigour and transparency of the process. The findings and participant quotes have been used in Section 8 to provide the user voice and evidence. It is planned that the study will be published in full in a peer-reviewed journal.
Appendix 5: Literature search strategy

**CINAHL search terms**

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<tr>
<td>S1</td>
<td>Splint* or cast or casts or casting or orthos*'s</td>
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<td>S2</td>
<td>Physiotherap* or ‘physical therap**’</td>
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<td>S3</td>
<td>((Brain or head) and injur*) OR (stroke or CVA or cerebrovascular accident) OR (“multiple sclerosis” or ms) OR neurology*)</td>
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<td>S4</td>
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<td>S5</td>
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This search was repeated with Occupational Therap* replacing Physiotherap* or ‘physical therap**’

**Medline Search terms**

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This search was repeated with Occupational Therap* replacing Physiotherap* or ‘physical therap**’

**AMED Search terms**

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<td>((splint* or (cast or casts or casting) OR (brace* or bracing) or (orthosis or orthoses)).af.</td>
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* Asterisks were used as a wild card symbol for truncation
Appendix 6: Sample documentation

Sample Patient Information: How to look after your splint/cast.

What is a splint/cast?
A splint/cast is a personalised supportive device to help you stretch or support a joint as part of your rehabilitation plan.

Why have I been given a splint/cast?
Splints/casts are used to improve or maintain range of movement at a joint. Make sure you are clear as to why this is useful for you.

E.g. To stretch a part of your body or to reduce pain.

When should I wear my splint/cast?
You should agree when to wear your cast and for how long with your therapist. Often this time frame increases as you become used to wearing it.

You agreed to ……………………………………………………………………….

Things to watch out for?
Please check your skin after you take off the cast for unusual signs e.g.

- Swelling
- Pain
- Redness
- Numbness
- Pins & needles
- Stiffness or
- Skin rash.
If you think the splint/ cast has caused any of these problems then, either ask for it to be removed or stop wearing it and please contact your therapist.

What should I do if there is a problem with my splint/ cast?

If it breaks or needs reviewing then please contact your therapist.

Cleaning my thermoplastic splint. (Add or remove as appropriate)

Remove straps and wash in warm soapy water, dry before wearing again. Note the shape your splint can be affected by direct heat, such as a hot radiator.

Any other questions?

Please contact your therapist, details below.

Address of department:
Therapist name:
Telephone number:
Patient name: | Who can put on/remove splint?
---|---
Named clinician: | Signature: Initial:
Description of splint: | Signature: Initial:
Signature: Initial:
Signature: Initial:

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<th>Time</th>
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Guidelines for using document:
- Splint to be worn as indicated by shaded area on timetable above.
- Tick the time and initial when putting on and tick the time and initial when removing having checked for potential pressure areas.

Monitoring advice for prevention of adverse events:
- Any staff putting on or removing a splint should check the skin for potential pressure areas.
- The splint must be removed if any adverse signs are noted e.g. Redness, skin breakdown, swelling, skin discoloration, visible or reported discomfort by the patient.

The named clinician to be informed as soon as possible.

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Appendix 7: a) Evidence-based review tables of included studies

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<thead>
<tr>
<th>Source</th>
<th>Design and participants (N) (including location and recruitment)</th>
<th>Intervention</th>
<th>Comparison (if applicable)</th>
<th>Outcome Measure/s</th>
<th>Results</th>
<th>Risk of bias, quality, grade and comment, (including limitations)</th>
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</thead>
<tbody>
<tr>
<td>Abdolvahab M, Bagheri H, Mahdizadeh H et al</td>
<td>Before &amp; after repeated measures</td>
<td>Volar static thermoplastic splint – wrist 10° ext, full ext fingers, abd &amp; opp of thumb</td>
<td>No control group</td>
<td>Spasticity – MAS</td>
<td>Wrist joint spasticity improved; pre 2.73±0.59 – post 1.60±1.12 (p&lt;0.0001) &amp; elbow joint spasticity improved pre 2.26 ±0.45 – post 1.26 ±0.88 (p&lt;0.0001)</td>
<td>Grade D – very low</td>
</tr>
<tr>
<td>(Translated paper from Persian)</td>
<td>Aim: evaluate effect of volar splint on spasticity &amp; function of adults with stroke</td>
<td>Plus usual care including Neurodevelopmental Treatment</td>
<td>Spasticity – MAS</td>
<td>Function - FMA</td>
<td>Function UL improved: pre 26.20 ± 15.58 - post 37.20 ±15.56 (p&lt;0.0001)</td>
<td>Downgraded from Grade C due to limitations:</td>
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<tr>
<td></td>
<td>N=15 (5M &amp;10F)</td>
<td>Dose = 2hrs/day &amp; 4 hrs/night for 2 months</td>
<td>PROM wrist &amp; elbow - goniometer</td>
<td>PROM wrist improved: pre 39.33° ±11.93 – post 71.66° ±8.79 (p&lt;0.0001)</td>
<td>PROM elbow improved: pre 118°± 20.51 – post 128.33°±6.98 (p&lt;0.002)</td>
<td>Risk of bias high. Limitations in study include:</td>
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<tr>
<td></td>
<td>Age 41-85 (mean 57.66 years)</td>
<td>Measures taken at weeks 0, 2, 4, 6, 8</td>
<td>Spasticity – MAS</td>
<td>PROM wrist improved: pre 39.33° ±11.93 – post 71.66° ±8.79 (p&lt;0.0001)</td>
<td>Although improvements are seen with splinting in this study, the limitations of study considerable and risk of bias very high.</td>
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<td></td>
<td>3.26 years post stroke (range 1-7 years)</td>
<td></td>
<td>Function - FMA</td>
<td>PROM elbow improved: pre 118°± 20.51 – post 128.33°±6.98 (p&lt;0.002)</td>
<td>Overstated claims given level of confounding factors and high risk of bias.</td>
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<td>1 year post stroke</td>
<td></td>
<td>PROM wrist improved: pre 39.33° ±11.93 – post 71.66° ±8.79 (p&lt;0.0001)</td>
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<td></td>
<td>MAS 1-2 in elbow &amp; wrist joints</td>
<td></td>
<td>PROM elbow improved: pre 118°± 20.51 – post 128.33°±6.98 (p&lt;0.002)</td>
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<tr>
<td></td>
<td>Hospital &amp; rehabilitation centres Iran</td>
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<th>Source</th>
<th>Design and participants (N) (including location and recruitment)</th>
<th>Intervention</th>
<th>Comparisons (if applicable)</th>
<th>Outcome Measure/s</th>
<th>Results</th>
<th>Risk of bias, quality, grade and comment, (including limitations)</th>
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<tr>
<td>Amini M; Shamili A, Forogh B et al</td>
<td>Pre, post test Aim: to examine effect of volar-dorsal splint on function of UL, ROM (elbow, wrist, MCP joints) &amp; spasticity in wrist &amp; elbow Stroke – min 1 year post N=14 (7M, 4F) Age 20-64 (mean 52.64 ±9.41) Hand spasticity ≤ 3 MAS No similar splints or botulinum toxin injections OT clinic – Iran</td>
<td>Volar-dorsal hand splint – wrist held in 10°ext, fingers 0°, thumb “hyper abduction” Plus routine OT 3 x week for duration of study</td>
<td>No control group</td>
<td>Spasticity: elbow &amp; wrist – MAS Function – FMA ROM (passive &amp; active): elbow, wrist, MCP – goniometer</td>
<td>11 people completed, 3 did not complete follow up. ITT analysis not evident. No change in ROM or spasticity (p&gt;0.05) Significant difference in UL function p=0.04 (Mean dif 2.09±2.98, t=2.32)</td>
<td>Grade D - very low. DOWNGRADED from Grade C due to limitations: Clinical significance of functional change not discussed; FMA is a measure of impairment. Risk of bias high, limitations include: • small convenience sample • no control group • assessor not blinded • co-intervention • no reliability data • data excluded for drop outs • FMA not OM of function Some indication of improvement in function but not in spasticity or range of movement but small study with high risk of bias. Overstated claims given level of confounding factors and high risk of bias.</td>
</tr>
<tr>
<td>Source</td>
<td>Design and participants (N) (including location and recruitment)</td>
<td>Intervention</td>
<td>Comparison (if applicable)</td>
<td>Outcome Measure/s</td>
<td>Results</td>
<td>Risk of bias, quality, grade and comment, (including limitations)</td>
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<tr>
<td>Basaran A, Emre U, Karadavut KI, Balbaloglu O &amp; Bulmus N (2012) Hand Splinting for Poststroke Spasticity: A Randomised Controlled Trial. Topics in Stroke Rehabilitation, 19 (4): 329-337</td>
<td>Single blinded RCT&lt;br&gt;Aim: determine effect of volar &amp; dorsal splinting on wrist flexor spasticity (+ range of movement)&lt;br&gt;N = 39 (22M &amp; 16F, + 1 unknown). Single stroke, wrist MAS ≥ 1+,&lt;br&gt;Age 26-81 (mean 55.6 years). Mean 38 months post stroke (range 5-120)&lt;br&gt;Could be on antispasticity medication if not changed for last 1/12&lt;br&gt;Exclusion included if worn splint within 8/52&lt;br&gt;Turkey, Rehab hospital (outpatients)</td>
<td>Expt groups:&lt;br&gt;Dorsal splint (DS)(n=13)&lt;br&gt;Volar splint (VS)(n=13)&lt;br&gt;All: home based exercise programme (including stretch wrist and finger flexors x 10 x 3/day)&lt;br&gt;Dose = splint to be worn up to 10 hours overnight for 5 weeks&lt;br&gt;“splinting position – beyond angle of “catch”, plus modified by 10° if stretch too much</td>
<td>No splint (NS)(n=12)&lt;br&gt;Plus home exercise programme (all groups)</td>
<td>Spasticity: MAS (6 levels) &amp; H latency &amp; Hmax:Mmax ratio&lt;br&gt;PROM wrist extension – double armed goniometer&lt;br&gt;Measures before &amp; after (5 weeks) at least 2 hours post removal of splint&lt;br&gt;Only electrophysiological measures were blinded.</td>
<td>No significant differences reported in any paradigm.</td>
<td>Grade B – moderate.&lt;br&gt;Downgraded from Grade A due to limitations:&lt;br&gt;Attempts to reduce bias:&lt;br&gt;• Control group&lt;br&gt;• Random allocation process&lt;br&gt;• Blinded assessor (electrophys OMs only)&lt;br&gt;• Drop outs reported&lt;br&gt;Limitations include:&lt;br&gt;• small sample&lt;br&gt;• assessor not blinded (MAS, PROM)&lt;br&gt;• no reliability data&lt;br&gt;• co-intervention not monitored&lt;br&gt;Overall no effect on spasticity, suggests dose not long enough. As primary study aimed at spasticity levels &amp; not PROM, splints were not to end range of muscle which maybe more effective.</td>
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<tr>
<td>Source</td>
<td>Design and participants (N) (including location and recruitment)</td>
<td>Intervention</td>
<td>Comparison (if applicable)</td>
<td>Outcome Measure/s</td>
<td>Results</td>
<td>Risk of bias, quality, grade and comment, including limitations</td>
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<tr>
<td>Beaty JA &amp; Murphy AL (2013) Effectiveness of a Flex Orthotic Splint on Hand Range of Motion for Older Adults: A Pilot Study.</td>
<td>Single Case Experimental Design (ABAA)</td>
<td>Flex orthotic splint (custom made)</td>
<td>n/a</td>
<td>RoM – flex/ext of hand joints (goniometer)</td>
<td>18/28 joints (64.3%) significant change over 8/52. 14/18 (77.8%) = positive change. 4 = negative change (DIP 5th, 4th, 2nd, and adb thumb) (see paper for individual results, too many to report) Satisfaction survey (n=7) – overall positive, greatest difficulty removing splint. Open comments – mixed reviews</td>
<td>Grade C – low Interesting study, user comments re using splints. Some indication of increasing ROM (all participants had contractures). Results must be viewed with caution: High risk of bias in study. Lack of control group Small sample size, underpowered study. Different assessors for each measurement point (attempt to blind)</td>
</tr>
<tr>
<td>Source</td>
<td>Design and participants (N) (including location and recruitment)</td>
<td>Intervention</td>
<td>Comparison (if applicable)</td>
<td>Outcome Measure/s</td>
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<tr>
<td>Booth, BJ. Doyle, M. Montgomery, J.</td>
<td>Retrospective case series</td>
<td>Serial casting (knee or foot)</td>
<td>No control group</td>
<td>Measures: Range of Movement (ROM) Scale for resistance to passive stretch (for muscle tone)</td>
<td>Long leg casts (knee, ankle and foot): (n = 5) Mean improvements in ROM (mean 17-26°) and Muscle Tone Recording: - Frequency of cast application - Results of lower extremity serial casting. Short leg casts (ankle and foot): (n = 39) Mean improvements in ROM (27° and 15°) and Muscle Tone. NB: some overlap seems to be indicated with a small minority of patients having both long and short leg casts.</td>
<td>Grade D - Very low. Downgraded from Grade C due to limitations • Early study identifying possible clinical benefits through description and clinical audit • High risk of bias • Requires evaluation of results before consideration for practice.</td>
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</table>

Serial casting for the management of spasticity of the head-injured adult. PHYSICAL THERAPY. 1983;63(12):960.

Seric casting for the management of spasticity of the head-injured adult. PHYSICAL THERAPY. 1983;63(12):960.

Records from 201 patients admitted to an adult head injury service were reviewed 21% underwent casting (cortical lesions most frequent, followed by brainstem ± cortical )

N = 42, mean age 23yrs
Acquired brain injury USA

Dose – 7-10 days between cast changes. (Worn 7-92 days)
Mean 78 days from time of injury to 1st cast

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<table>
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<tr>
<th>Source</th>
<th>Design and participants (N) (including location and recruitment)</th>
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<th>Results</th>
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<tr>
<td>Burge E, Kupper D, Finckh A et al. Neutral Functional Realignment Orthosis Prevents Hand Pain in Patients with Subacute Stroke: A Randomized Trial. Archives of Physical Medicine &amp; Rehabilitation. 2008; 89: 1857-1862</td>
<td>RCT Aim: quantify preventative effect of neutral functional realignment orthosis on ROM, pain, mobility &amp; oedema. N=31 (1 withdrew post group allocation), Expt: n=16, age 68 ±12, M6, F9, 29 days ± 15.7 (15-74) post stroke Control : n=15, mean age 64 ±14, M5, F10, 30 days ± 12.1 (12-57) post stroke Inpatient rehab centre Switzerland</td>
<td>Standard rehabilitation + realignment orthosis (custom made splint by OT) Dose: splint (neutral position) worn min 6 hrs /day up to 13 weeks. Rehab: 2xPT/day, 1x OT/day plus SLT and psychology if needed.</td>
<td>Standard rehabilitation only Rehab: 2xPT/day, 1x OT/day plus SLT and psychology if needed.</td>
<td>FMA - ROM (forearm, wrist &amp; hand) MAS – wrist ext tone VAS - Hand pain at rest Wrist circumference – oedema Verbal - Patient satisfaction</td>
<td>Pre – 2 patients in each group c/o painful hand. Post – 8 patients in control group had pain, 1 patient in expt group (P=.004) ROM, MAS &amp; oedema – no statistically significant change. May have preventative effect on post-stroke hand pain but not mobility or oedema. Subanalysis = wearing splint ≥10 hrs same as 6 hrs</td>
<td>GRADE A – High Well conducted study: • Random concealed allocation, • Groups well balanced • Control group • reliability data • blinding in practice difficult as patients spoke about splint Some indication for use of hand splint for prevention of hand pain post stroke but more replication of study required.</td>
</tr>
<tr>
<td>Source</td>
<td>Design and participants (N) (including location and recruitment)</td>
<td>Intervention</td>
<td>Comparison (if applicable)</td>
<td>Outcome Measure/s</td>
<td>Results</td>
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<td>Case-control study</td>
<td>N=65 Stroke (n=55), TBI (n=7), other CNS (n=3)</td>
<td>Group 1: BTX + Strapping – dose = 6 days taping</td>
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<td>High risk of bias.</td>
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<td>Group 2: BTX + Splinting and FES + stretching exercises</td>
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</table>

However group 1 had significantly better reductions in spasticity than group 2 (MAS).

- Significant limitations in measurement in only evaluating spasticity outcome. No blinding of assessor
- No random allocation (based on hospital attended)
- Does not support the use of splinting in combination with functional electrical stimulation
<table>
<thead>
<tr>
<th>Source</th>
<th>Design and participants (N) (including location and recruitment)</th>
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<th>Risk of bias, quality, grade and comment, (including limitations)</th>
</tr>
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<tr>
<td>Carda S, Invernizzi M, Baricich A, Cisari C.</td>
<td>Single-blind, randomized trial, with three-month follow-up. N=69 Stroke Average 47.7 (41.5 SD) months since stroke Mean age 62.1 Italy</td>
<td>Post botulinum toxin type A injection in plantar flexors, patients randomly assigned to 3 groups &amp; received either: - taping, - casting or - stretching for one week, + stretching &amp; gait training for next week.</td>
<td>3 intervention groups, no control group</td>
<td>T1 20 days, T2 90 days MAS PROM at the ankle Six-minute walking test 10-metre walking test, Functional Ambulation Categories (FAC) Ankle dorsiflexor strength</td>
<td>Significant improvement in the casting group at all timepoints for PROM, MAS, 6 minute walk, 10m walk. Taping – all significant at T1, only MAS &amp; 6 min walk at T2 Ankle DF strength &amp; FAC no changes at any timepoints.</td>
<td>GRADE B – moderate. Downgraded from Grade A due to limitations: - Some risk of bias, but reasonably robust study with single blind design. - Groups similar at baseline - Blinded assessor - Computer randomisation - Provides evidence for the effectiveness to serial casting in adult stroke patients for the ankle joint.</td>
</tr>
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<tr>
<td>Charait SE. A Comparison of Volar and Dorsal Splinting of the Hemiplegic Hand. American Journal of Occupational Therapy. 1968; XXII (4); 319-321</td>
<td>Before and After (pilot)</td>
<td>Volar or dorsal splint</td>
<td>No control group</td>
<td>Spasticity – clinical observation</td>
<td>Volar splints – increased spasticity in 6 (4 marked), 4 no change in spasticity or voluntary movement</td>
<td>Grade D – very low Downgraded from Grade C due to limitations. Early study that engaged with the splinting debate at the time; high risk of bias. Uncontrolled study with multiple biases including sample/selection, measurement. Patients who showed best results only wore splints at night. All patients wearing splints for 23 hours complained of pain in hand and entire arm.</td>
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<td></td>
<td>N=20 (10 = volar; 10 = dorsal)</td>
<td>Dose = 2 to 23 hours per day (removed for therapy and bathing).</td>
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<td>Range of movement: wrist and finger extension – not stated how measured</td>
<td>Dorsal splints – no change in outcomes in 1; one considerable increase in spasticity, 8 decrease spasticity (4 with improved active finger &amp; wrist extension)</td>
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<td>10 M; 10 F, aged 30-80 years.</td>
<td>Usual care = passive or active ROM exercises, average 30 mins/day x 5/week, plus OT (incl graded resisted ex’s), 30 mins/day x 3/week</td>
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<tr>
<td></td>
<td>9 R hemiplegia</td>
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<td></td>
<td>11 L hemiplegia</td>
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<td>Splint applied post stroke 4 days to 6 years.</td>
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<td></td>
<td>USA – rehab inpatients and outpatients</td>
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<tr>
<td>Conine TA, Sullivan T, Mackie T, Goodman M.</td>
<td>Prospective case series, before and after (pilot)</td>
<td>Serial casting within 14 days of TBI plus usual care</td>
<td>No control group</td>
<td>1. PROM DF of ankle – goniometer</td>
<td>Mean gain pre-post cast = 21° P&lt; .05</td>
<td>Grade C - low Well carried out study within design limitations.</td>
</tr>
<tr>
<td>Effect of Serial Casting for the Prevention of Equinus in Patients with Acute Head Injury. Archives Physical Medicine &amp; Rehabilitation. 1990; 71: 310-312</td>
<td>Aim: to examine the effect of serial casting for prevention of equinus in patients with acute head injury. N=10 (8 M; 2 F) (18 limbs, 16 bilateral) Average 28 years, GCS &lt; 10 on adm PROM DF ≤ 0° Inpatient acute care Canada</td>
<td>Dose: cast removed after 5-7 days Cast replaced if unable to maintain DF at ≥ 0° for 1 hour. Final cast bivalved &amp; worn 18 hours/day (4 hr on/1 hr off)</td>
<td></td>
<td>2. Skin condition – visual inspection Inter-rater reliability Blinded assessor</td>
<td>13/18 limbs reached PROM DF of ≥ 0° (maintained without force for min 1 hr) Adverse event - 1 small pressure sore</td>
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<td>Conclusion: procedure appears safe, reasonably efficient in carefully selected population.</td>
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© College of Occupational Therapists & Chartered Society of Physiotherapy: Practice Splinting Guideline

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</table>
Aim: to evaluate effect of 12 week dynamic progressive orthotic splint on people with stroke + wrist flexion contracture  
N=6, 4F, 2M  
Mean age 61 years (range 53-71), min 1 year post stroke  
1/5 on Modified Ashworth Scale  
Nursing home facility USA | Custom fitted serial adjusted wrist extension orthotic /splint *(Dynasplint)  
Dose: 4 hours/ day, 4/week for 12/52  
(NB: dynasplint recommend 6-8hrs/day)  
* fitted and adjusted periodically by Dynasplint representative to obtain max comfortable wrist extension  
Investigators put splint on and off each day | No control group | 1. PROM wrist goniometer  
2. RTPM (resistance to passive movement) - MAS and Modified Tardieu Scale (MTS)  
3. Surface EMG - RTPM  
Inter-rater reliability (ICC 0.76)  
Blinded assessor (to study objectives) took measures weekly (baseline established), & 2, 4 & 6 weeks post intervention | 5/6 people showed increased PROM and decrease in RTPM.  
A moderate effect size found PROM pre-post 0.67, PROM post retention 0.60  
EMG burst onset 0.62 (indicates less RTPM)  
MAS, MTS – min effect sizes  
Conclusion: Dynasplint can be effective in increasing wrist ext in people with chronic stroke + flexion contracture and decreasing RTPM. Compliance assisted by investigators donning and doffing splint throughout study. | Grade C - low  
Well carried out study within design limitations.  
- Small sample size  
- Inherent biases in study design e.g. no control group, not randomised  
- Need RCTs to further assess efficacy of dynasplint. Also to investigate if recommended dose of 6-8 hrs daily better than the 4hr/day.  
Suggests can effect non neural aspects of RTPM but not neural. |
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| Farina S, Migliorini C, Gandolfi M, Bertolasi L, Casarotto M, Manganotti P, et al. | Randomised study design. Patients with equinovarus foot randomised to two groups N= 13 Stroke – 6/12 to 2 years post stroke Italy | Group 1 | Group 2 BTA alone (n=7). No control group. | Static and dynamic baropodometric Tests Modified Ashworth Scale 10-meter walking test. | Between groups: Small significant differences seen in support area during gait and in spasticity but clinical significance doubtful. No significant difference in 10 meter walk. | Grade B – moderate. Downgraded from A due to limitations:  
• Some weaknesses in the study (possibly also in the casting intervention, although not possible to confirm).  
• Some aspects of reporting, such as description of sampling missing.  
• Lack of demonstration of clinical significance and applicability of findings. |
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<tr>
<td>Fayez, S E, Sayed, H M</td>
<td>Randomised controlled trial</td>
<td>Two groups</td>
<td>No control group</td>
<td>Active range of movement (A-ROM)</td>
<td>Both groups showed significant improvements from baseline in all three measures.</td>
<td>Grade C - low (downgraded from grade A)</td>
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<td>Grip strength – digital dynamometer</td>
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- The general reporting of the study poor. No reporting of randomisation, how measurements were performed
- The very short duration of intervention, results in the work not addressing clinically relevant or applicable intervention.
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<td>Grissom SP &amp; Blanton S. Treatment of Upper Motoneuron Plantarflexion Contractures by Using an Adjustable Ankle-Foot Orthosis. Archives of Physical Medicine &amp; Rehabilitation 2001; 82: 270-3.</td>
<td>Prospective non-randomised intervention trial (before &amp; after pilot) Aim: assess effectiveness of adjustable AFO splint in treatment of PF contracture in CNS damage or disease N=6 (2M, 4F) stroke, TBI, ICH, AVM (9 ankles) Age 21-62 PROM DF ≤ 0°, &lt;5° change PROM post 2% lidocaine block (to differentiate between spasticity &amp; contracture) Inpatient acute care USA</td>
<td>Adjustable AFO splint (prefabricated commercially available) plus usual care Adjustment of angle of orthosis from 0° to 4.5° every 48-72hrs as tolerated. Dose: 23/day for 14 days (only removed for hygiene purposes)</td>
<td>No control group</td>
<td>DF PROM with knee extension – goniometer (ICC intra-rater &gt;.90) Unblinded assessor</td>
<td>Increased PROM average (pre/post) 20.1°, range 6-36° (p=.0078) 5 completed study (1 drop out, concerns about increased agitation in person with TBI) Adverse events: 44% ankles reported redness of skin, or blister formation with pain Conclusion: PF contractures can be reduced with adjustable AFO. NB – careful monitoring required as high rate of adverse events</td>
<td>Grade D – very low. Downgraded from Grade C due to limitations. Limitations in keeping with study design including: • Lack of blinding of assessors • no control group • co-intervention •lack of standardisation of force to achieve DF of ankle •small sample Very small study with some indication of increased passive dorsiflexion. Results need to be duplicated in RCTs and larger cohorts.</td>
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<td>Harvey L, de Jong I, Goehl G, Mardwedel S. 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. 2006;52(4):251-8.</td>
<td>RCT – within and between design N= 44 participants (60 thumbs incorporating bilateral intervention in some people) 14 stroke, 7 TBI, 23 SCI Median age 54 (IQR 43 to 65) Median time since onset 4 years (IQR 2 to 10) 55 thumbs 0 or 1, 5 thumbs 2 or 3 (Ashworth) Australia – inpatients and outpatients</td>
<td>Thermoplastic splint to keep thumb in abduction (c splint or cone splint). Text implies stretch at end of range. Dose – 12 weeks, overnight 8 hours/night (minimum of 84 nights) Experimental and control groups told not to stretch, no other intervention received. Expt group received phone call 1-2 weeks to monitor compliance. Splints reviewed at 1, 4 and 8 weeks.</td>
<td>Control – no splint to stretch thumb web space, no contact over 12 weeks (NB: n=10 had old splints modified to exclude thumb from stretch and allowed to wear)</td>
<td>Baseline, 12 weeks (one day post study) MCID set at 5° a priori at CMC joint.</td>
<td>1 drop out (2 thumbs) No sign difference between groups at baseline. Mean increase 1° (95% CI, -1 to 2). Adverse events reported: minor problems with skin breakdown (median 4 out of 84 nights missed due to skin related problems).</td>
<td>Grade A – high Well conducted study: Random allocation blocked to diagnosis (post baseline), Concealed allocation, Assessor blind Power calculation Results indicate that in this study stretch over 12 weeks does not change tissue extensibility in the thumb web space.</td>
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<td>Hill J.</td>
<td>Randomised case control cross over trial</td>
<td>Group 1: (casting intervention month 1; standard care month 2)</td>
<td>Group 2: (Standard care month 1; casting intervention month 2)</td>
<td>ROM (goniometer)</td>
<td>Casting showed a significant reduction on spasticity (P=.001) and PROM (P=.014)</td>
<td>Grade C – low. Downgraded from Grade A due to limitations:</td>
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<td></td>
<td>Inpatient population consecutive sample (single service)</td>
<td>Circular elbow or wrist casts or both applied (5 to 10° off max ROM)</td>
<td>Standard care included: passive &amp; active ROM, prolonged stretch, splinting (including bi-valved casts worn intermittently), neurophysiological techniques (e.g. neurodevelopmental treatment, proprioceptive neuromuscular facilitation) &amp; relaxation techniques.</td>
<td>Joint angle of catch on fast muscle stretch</td>
<td>Results on function were non-significant (P=.347)</td>
<td>- Intervention &amp; standard care very closely related in this study.</td>
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<td></td>
<td>N=15</td>
<td>Details of casting application given.</td>
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<td>Functional tasks</td>
<td></td>
<td>- Limited application, with no overall significant difference shown in all areas, but spasticity.</td>
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<td>Age 9-48 (mean 28.5)</td>
<td>Applied for 5-7 days for 1/12</td>
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<td>- May give indication for future evaluation but cannot dictate practice.</td>
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<td></td>
<td>Acquired Brain Injury (no more than 2 years post injury)</td>
<td>USA</td>
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<td>- Conclusion states casting more effective than traditional methods, which is overstating the findings in the paper</td>
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<td>USA</td>
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<tr>
<td>Jung YJ, Hong JH, Kwon HG, Song J-C, Kim C, Park S, et al.</td>
<td>RCT</td>
<td>N=10</td>
<td>N=11</td>
<td>modified Ashworth scale (MAS)</td>
<td>Intervention group: the average of mean MAS score between Pre-1 and Pre-2 was not significant (P &gt;0.05). Significant improvement post intervention (P &lt;0.001) using one-way repeated measures ANOVA test for evaluation of effect across all time-points.</td>
<td>Grade C – low. Downgraded from Grade A due to limitations:</td>
</tr>
<tr>
<td>The effect of a stretching device on hand spasticity in chronic hemiparetic stroke patients. NeuroRehabilitation. 2011;29(1):53-9.</td>
<td>Chronic hemiplegic stroke patients recruited from stroke services. Rigorous exclusion criteria applied. Stroke – min 6 months post</td>
<td>Stretching device: resting hand splint, finger stretcher, and frame. The stretching state was maintained for 30 seconds and relaxed for the next 30 seconds repeated for 20 minutes (one session). The stretching program was practiced 2 sessions per day and 6 days/week for 3 weeks</td>
<td>No intervention</td>
<td></td>
<td>• Comparison between intervention and control groups not presented. • Small sample size • No details of randomisation or allocation • Outcome assessor not blinded • Clinical difference not evaluated. • No significant difference likely in this study. • Intervention unlikely to be practical in practice.</td>
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| Lai JM, Francisco GE, Willis FB (2008) | Controlled cross over trial  
Aim: to examine the efficacy of low load, prolonged duration stretch with a dynamic splint for ankle contracture  
Recruited volunteer sample n=50 people ≥ 1 year post stroke (n= 30) or TBI (n= 20).  
All had existing PF contracture  
Age = not provided  
Outpatient facilities USA | Custom fit Dynamic ankle DF (AFD) splint (dynasplint)  
Standard protocol (including heat, education, joint mobilisations, self-stretch at home) 2x per week for 6/12  
Cross over expt group (n=35, 21 stroke, 14 TBI)  
Dose (splint) = 6-8 hrs overnight for 12/52 i.e. additional 42 to 56 hours per week  
end ROM therapy  
Diary kept of wearing times. Tension increased as DF improved, (based on tolerance) | ’Non- expt group’ (n=10, 5 stroke, 5 TBI)  
Standard protocol (including heat, education, joint mobilisations, self-stretch at home) 2x per week for 6/12 | PROM (ankle DF) - goniometer  
Measured at enrolment, 3 (cross over) and 6 months | N= 45 (5 dropped out due to non-compliance).  
Statistically sign change in PROM in expt cross over group p=0.0007, F=4.795, between cross over groups NS  
Expt Stroke Pre -7.4 ±29.1Post 24.2 ±23.9  
TBI Pre -14.1 ± 31.8  
Post 11.5 ± 29.7  
Control Pre -7.9 ±28.7  
Post -10.1 ±29.9  
No adverse reactions reported | Grade C - low  
Risk of bias high.  
Study limitations include:  
• Participants selected for cross-over based on ‘physicians prescription of the AFD’  
• outcome assessor not blinded  
• incomplete data not accounted for (5 drop outs)  
• Expt cross over group showed greater improvement in DF PROM.  
• Possible purposive selection of intervention group with risk of bias  
• Authors suggest using AFD allows therapists to focus on higher rehab challenges including motor skill acquisition. |
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<td>Lannin NA, Horsley SA, Herbert R, McCluskey A, Cusick A. Splinting the hand in the functional position after brain impairment: a randomized, controlled trial. Archives of Physical Medicine &amp; Rehabilitation. 2003a;84(2):297-302.</td>
<td></td>
<td>Splint applied in functional position 10-30° ext at wrist plus usual care (including UL use = 30 mins/day 5x7 week and UL stretches = 2x 30 mins 5/7)</td>
<td>Usual care including UL use = 30 mins/day 5x7 week and UL stretches = 2x 30 mins 5/7</td>
<td>Baseline, end of study 4/52, and 38th day post intervention (follow up)</td>
<td>Participants in both groups similar at baseline. 5° MCID a priori (p≤ .05) Effects of splinting statistically non-significant mean 1° after intervention (95%CI, -3.7 to 6.1°) At f/u mean 2° (95%CI, -7.2 to 3.2°) – favoured control group. No adverse events reported.</td>
<td>Grade B – moderate. Downgraded from Grade A due to limitations: Overall a well conducted study but key co-intervention not addressed. • Not possible to blind therapist and patients. • Blinded assessment of outcome measures, • Valid outcome measures Splinting in functional position (i.e. not at end range) does not produce beneficial effects in adults receiving UL training &amp; stretches.</td>
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<td>Lannin NA, Cusick A, McCluskey A, Herbert RD. Effects of splinting on wrist contracture after stroke: a randomized controlled trial. Stroke 2007;38(1):111-6.</td>
<td>Multicentre RCT N= 62. Control = n=21 (9M, 12 F; 75.4 yrs ±11.00), Neutral = n=20 (9M, 11 F; 70.3 yrs ± 12.6), extended (n= 21, 12M, 9F; 68.7yrs ± 12.1) Within 8 weeks of stroke, 18 +, with no active wrist extension Sydney Australia – 9 inpatient stroke and rehabilitation units</td>
<td>Overnight wrist splint in either neutral or extended wrist (&gt; 45°) position plus usual care Dose = 28 night, up to 12 hours/night. Total maximum of 336 hours. No stretches of wrist/long finger flexors allowed. Max 10 mins isolated wrist &amp; finger extension practice each day.</td>
<td>Usual care No stretches of wrist/long finger flexors allowed. 10 mins isolated wrist &amp; finger extension practice each day.</td>
<td>Baseline, post (4/52), 12-24 hours post splint removal, f/u 6 weeks. Primary: Extensibility wrist &amp; finger flexors – standardised torque Wrist extension – lateral photographs Secondary: UL function – Motor assessment scale Spasticity – Tardieu Disability – DASH</td>
<td>5° MCID a priori Neutral wrist splint increased wrist ext mean 1.4° (95% CI, -5.4 to 8.2°) Wrist in extension reduced wrist ext by mean 1.3° (95% CI, -4.9 to 2.4°) On average lost 17° wrist range of movement at end of 6/52 study.</td>
<td>Grade A - high Well conducted study within study limitations e.g. •Not possible to blind therapist and patients. •Blinded assessment of outcome measures, •Valid outcome measures Recommends routine practice of hand splinting to prevent contracture to be discouraged in people with stroke.</td>
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<td>Lehmkuhl LD, Thoi LL, Baize C, Kelley CJ, Krawczyk L, Bontke CF.</td>
<td>Retrospective cohort analysis of clinical records (with follow up) Based in a single rehabilitation unit. N=25 (16M, 9F) Age 3-54, mean 25 years Approx 6/12 between injury &amp; 1st cast Acquired Brain Injury USA</td>
<td>Serial casts applied at elbow, knee and ankle. N= 21 elbow casts (av 12/7, changed every 3/7) N= 7 knees (av 15/7, cast changed every 3/7) N=14 ankles (av 22/7, changed 5-7/7)</td>
<td>n/a</td>
<td>Range of movement</td>
<td>Significant post intervention improvement in ROM at 3 joints (&amp; mostly maintained). Average pre - 50.0±26.00, post - 23.3± 16.8 (p&lt;0.001) Elbow ext most successful then kn next. Elbows &amp; knees respond quicker than ankles. Used orthotic device to maintain gains Adverse events: 1 case of skin breakdown 1 cut when removing cast</td>
<td>Grade D – very low  • Evident risk of bias due to lack of control and retrospective nature of study.  • Indication of the benefit of serial casts in improving range of movement in this patient group.  • Raises useful questions for future evaluation in a systematic manner</td>
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<td>Leung, J Harvey, L A Moseley, A M Tse, C Bryant, J Wyndham, S Barry, S</td>
<td>A multi-centre randomised trial (RT) with concealed allocation. N=36 Stroke (n= 31) or TBI (n=5) Expt n=18, age 66 (57-75) Cont n =18, age 48 (34-62) Time post stroke average 55 days (32-94) Australia</td>
<td>4-week programme of intervention for both groups. Custom-made hand splints for 12 hours per day for between 5 &amp; 7 days per week. The experimental group received electrical stimulation to the wrist &amp; finger extensor muscles for 1 hour a day over 4 weeks.</td>
<td>Splint only</td>
<td>Assessor blinding Primary: passive wrist extension measured with 3 Nm torque &amp; fingers in ext. Secondary: passive wrist ext, wrist &amp; finger ext strength (dynamometer), wrist flexor spasticity (tardieu scale), motor control of the hand (Motor Ax Scale), &amp; Global Perceived Effect of Treatment, &amp; perception of treatment credibility</td>
<td>ITT analysis At 4/52 mean between-group difference for passive wrist ext was 7 degrees (–2 to 15) &amp; at 6/52, –3 degrees (–13 to 7). Secondary outcomes: statistically non-significant (or were of borderline statistical significance).</td>
<td>Grade A - high</td>
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- Robustly conducted study, with appropriate statistical analysis and clear reporting.
- The authors concluded that a clear meaningful treatment effect was not produced, which is a robust conclusion given the remit of the study.
- However significant changes were seen and intervention over longer duration (higher dose as recommended by the authors) may produce clinically meaningful effects.
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<tr>
<td>Moseley A M. The effect of a regimen of casting and prolonged stretching on passive ankle dorsiflexion in traumatic head-injured adults. Physiotherapy Theory &amp; Practice. 1993;9:215-21.</td>
<td>Prospective case series (before and after) N= 19 (1F, 18M) (32 casted limbs, 16 R, 16 L). Average age 27.9 ± 10.2 years (range 16-50) LOC(days) 21.6 ±11.3 (range 10-42) Median 90 days (36-648) post injury All had decreased passive DF (heel unable to reach ground) Australia – inpatient rehabilitation</td>
<td>Below knee cast + Stretching of calf muscles with knee extension e.g. tilt table, long sitting (min 1 hr /day) + motor training programme including sit to stand, standing, walking. Dose = 7 days</td>
<td>No control group</td>
<td>Pre and post cast Passive DF – DF of ankle with known torque, photo of DF angle</td>
<td>Mean increase passive DF 10.4° ± 8.7 (p&lt;0.001) n=28 increased DF between 3 and 36° n= 3 decreased 1 &amp; 8° n=1 no change</td>
<td>Grade C – low Overall a well conducted clinical study but number of limitations, so risk of bias: • Small sample size • no control group unclear • co-intervention variability in active task practice • Need RCTs to further assess efficacy of casting. Findings suggest casting &amp; prolonged stretching is effective for correcting calf muscle shortening</td>
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<td>Moseley AM, Nicholson D, Riolo L, Wiggs L, Rothstein J. The effect of casting combined with stretching on passive ankle dorsiflexion in adults with traumatic head injuries. Physical Therapy. 1997;77(3):240-59.</td>
<td>RCT cross over N=9 (1F, 8M), average age 29.1 ±11.0. Time post injury 29-110 days (average 72.2 ± 27.1) All needed help to stand, decreased DF, unable to get heel to floor. (corrective) Australia – brain injury units (inpatients)</td>
<td>Casting and stretching (1 hour/day) Plus motor training programme (included walking, standing, sit to stand) Dose = 7 days (cast), 1 hour (stretch knee/gastrocnemius)</td>
<td>No casting or stretching</td>
<td>Before &amp; after 0, 1 week, 2 weeks. Passive DF - torque controlled + photograph of ankle</td>
<td>Mean increase of 13.5° ± 9.3 DF with casting for 7 days plus and stretching for 1 hour/day. Control group = 1.9° ± 10.2. (mean difference of 15.4° P&lt;.05)</td>
<td>Grade B – moderate Downgraded from grade A due to limitations Overall a well conducted study but limitations, so risk of bias medium: • Small sample size • unclear randomisation, allocation concealment etc •co-intervention variability in active task practice •need longer term follow up •Need RCTs to further assess efficacy of casting. Findings suggest casting combined with stretch is effective in decreasing PF contractures in TBI</td>
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<td>Moseley AM, Hassett LM, Leung J, Clare JS, Herbert RD, Harvey LA. Serial casting versus positioning for the treatment of elbow contractures in adults with traumatic brain injury: a randomized controlled trial. Clinical Rehabilitation. 2008;22(5):406-17.</td>
<td>Pragmatic RCT N= 26 (n=12 positioning, n=14 casting) Mean age 31.5 ±11.2 23M, 3F Median 65 days (IQR 51-173) post injury Australia</td>
<td>Serial casting + individual therapy programme + exercises with the study arm for 15mins/day Dose: casts 2/52. Casts changed at 1 week or earlier</td>
<td>Positioning (stretch for 1 hour/ day, or 2x 30 mins /weekday) (some 1 hr/day at w/e by family) + individual therapy programme + exercises with the study arm for 15mins/day</td>
<td>Baseline, post (2/52), post 2/52 plus 1 day, follow up 4/52. Primary: Elbow extension – standardised torque (spring balance), angle with digital inclinometer Secondary: Spasticity – modified Tardieu Max reach – sternum to table UL function – TEMPA Pain – VAS Perceived effect &amp; difficulty of treatment – Likert scale</td>
<td>No clinically important differences between groups at baseline. Serial casting= Post – increased 22° (95% CI, 13 to 31, p&lt;0.001) Post + 1 day – increased 11° (95% CI, 0 to 21, p=0.052) F/U – increased 2° (95%CI, -13 to 17, p=0.782) Serial casting group had lower spasticity &amp; better perceived treatment</td>
<td>Grade B –moderate. Downgraded from Grade A due to limitations: Mostly well conducted study: • allocation concealment • blinded assessors •co-intervention variability •sequence generation not clear •likely underpowered •Need RCTs to further assess efficacy of casting. Initial change significant but lost at f/u 4/52. Change may be sustained if active elbow ext.</td>
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| Pohl M RcS, Mehrholz J, Ritschel C, Strik H, Pause MR. | A retrospective case-comparison study.  
Single centre  
N=105  
ABI (n=67) and stroke (n=38)  
Average age 41.4  
24F, 81M  
Germany | Serial casting of 172 joints (42 elbow, 41 wrist, 21 knee, 68 ankle joints), with cast-changing intervals of 5 to 7 days  
Comparison of cast changing intervals:  
**Group 1:**  
5 to 7 days (92 joints, 56 patients).  
**Group 2:**  
1 to 4 days (80 joints, 49 patients). | None | Percentage of normal maximum range of motion (ROM) at the completion of casting and 1 month after discontinuation, and the number of complications resulting from the casting procedure. | Improved ROM immediately after serial casting and 1 month later in both groups (F=1469.5, P=.001). No differences in ROM improvement between groups were observed (F=0.3, P=.72).  
Complications in serial casting were found in 19.8% (n=34) of 172 casting procedures (29.3% in group 1 and in 8.8% in group 2; X=10.2, P=.001).  
Discontinuation of treatment because of casting complications/other reasons observed in 12.8% (n=22) of the entire sample, (18.5% in group 1 and in 6.3% in group 2; X=4.7 P=.03). | Grade C- low  
- Casting effective in treatment of fixed contractures of upper & lower extremities caused by increased muscle tone of cerebral origin. Short changing intervals in serial casting provided improvements in ROM comparable with conventional changing intervals, and resulted in fewer complications.  
- Retrospective case control following a change in practice.  
- However well conducted study. |
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| Pohl M, Mehrholz J, Ruckriem S. | Retrospective case-comparison study. To compare the improvement and complication rates for serial casting in patients with shorter as opposed to longer illness duration, and in patients with lower as opposed to higher levels of consciousness. (knees) Stroke & ABI Setting – single center N=68 Average age 45.2 Germany | Primary Analysis: **Group A**, (n=24) Serial casting before 90 days. **Group B**, (n=44) Serial casting at 90 days or more. Secondary Analysis: **Group 1**, (n=25) Glasgow Coma Scale (GCS) score of less than 12. **Group 2**, (n=43) Glasgow Coma Scale (GCS) score of 12 or more. **Dose** Median casting days = 8.25, casts changed median 2.5 days | Percentage of normal maximum range of motion (ROM) at the completion of casting and one month after discontinuation, and number of complications due to casting procedure. Functional Independence Measure (FIM) Modified Ashworth Scale Glasgow Coma Scale | No differences in ROM between duration groups (F = 0.43, p = 0.51) and GCS groups (F = 1.3, p = 0.26) were observed. Complications in serial casting were found in 25.0% (6/24) in group A, in 10.6% (7/44) in group B, in 24.5% (6/25) in group 1, and in 8.3% (3/43) in group 2. | Grade C - low  
• Risk of bias due to retrospective nature.  
• Suggests serial casting in patients with longer illness duration & higher levels of consciousness provides improvements in ROM comparable with earlier casting intervention in patients with more impaired consciousness, but results in a lower occurrence of complications.  
• Relevant on HOW to practice |
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N = 30 (16 splint, 14 tilt table)  
13F, 17M, average age 72 (SD 10),  
within 3/52 of stroke average 12 days post stroke (SD 5)  
Australia – in and outpatients | Night splint – ankle at plantar grade (off shelf or “temporary custom made”)  
Dose: Splint – 7/7 for 4/52  
+ inpatient rehab 5/7 early weight bearing & mobility or outpatient rehab – 1 or 2 x week  
NO other intervention aimed purely at DF | Tilt table – max DF with use of wedge  
Tilt table – 30 mins x 5/week for 4/52  
+ inpatient rehab 5/7 early weight bearing & mobility or outpatient rehab – 1 or 2 x week | Pre, post (4/52), follow up (6/52 later)  
Primary: Passive DF ankle – spring gauge known torque  
Secondary: Stand up from chair 45cm high (item 4 of motor assessment scale) | Splint group DF = tilt table DF at 4/52 mean difference 1°, 95%CI -5 to 7 and 10/52 mean difference 3.5°, 95%CI -3 to 10.  
Compliance: Splint = 73%  
Tilt table = 87%  
Adverse events: pressure sores x 2 (splints not custom made) Pain/heat/tight x 5 | Grade B – moderate  
Downgraded from Grade A due to limitations  
Well conducted trial, inherent biases as no control group  
• power calculation  
• co-intervention  
• concealed allocation  
• intention to treat analysis  
• Need RCTs to further assess as prevention of contracture may have been due to other factors  
When added to early rehabilitation, wearing a night splint is as effective as standing on a tilt table for the prevention of ankle contracture following stroke. |
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<td>Shamila A, Amini M, Forough B, Kazemi R, Qorbani M (2011)</td>
<td>Case comparison N = 28 but N= 18 completed the study. (Only reports completed data) &gt; 1 year post onset of stroke Toxin group – Average 48 years, 7 F, 2 M Splint group – average 52 years, 4 F, 5 M All max 3 on MAS Rehabilitation Units Tehran Iran</td>
<td>Volar/dorsal wrist/hand splint – wrist in 10° ext., fingers 0° Dose = 2hrs/day + 6-8 hrs at night for 3/12 Or Botulinum toxin type A + all participants received occupational therapy x3/week</td>
<td>No control group</td>
<td>Measures taken baseline, 1/12 &amp; 3/12 PROM – goniometer MAS – spasticity FMA – function</td>
<td>N=18 Generally poor reporting. Appears similar results in both groups (most outcomes improved), all non significant between groups and (p&lt;.05) but different timescales i.e. toxin change noted earlier compared to slower change with splint.</td>
<td>Grade D – very low Downgraded from Grade C due to limitations High risk of bias with many limitations in study design: • no control group • no details on outcome assessor, any blinding, reliability etc • small sample size • High drop out rate and no intention to treat analysis • co-intervention • FMA is not a measure of function but impairment.</td>
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| Singer BJ, Jegasothy GM, Singer KP, Allison GT. Evaluation of serial casting to correct equinovarus deformity of the ankle after acquired brain injury in adults. Archives of Physical Medicine & Rehabilitation. 2003a;84(4):483-91. | Prospective repeated measures design N=16 (n=19 limbs, all had contracture or decreasing range & overactivity) 11M, 5 F, age 17 to 52 TBI, ICH, SAH – 3 to 10 months post injury All non-ambulatory Australia – inpatient | Below knee cast Predetermined discontinuation criteria = if no gains <5° of ankle PROM DF over 3 casts. If PROM 10° with knee extension then resting splint made. + individualised therapy programme | No control group | Baseline 5 measures pre casting, post initial cast, midpoint cast, after final cast (1 week post cast) Max ankle DF (knee ext & flexed) – goniometer Ease of transfer from bed to chair – transfer dependency scale (prior & 3/12 follow up) | Significantly improved ankle ROM: Knee flexed = mean 18° Knee extended = mean 16° P<.0001. 13 participants reduced need for transfer assistance P<.0015 | Grade C - low Well carried out study within design limitations.  
• Small sample size  
• Inherent biases in study design e.g. no control group, not randomised  
• Need longer term follow up Uncontrolled study that gives positive indication of casting for improving ankle DF in ABI. |
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<tr>
<td>Singer BJ, Singer KP, Allison GT. Evaluation of extensibility, passive torque and stretch reflex responses in triceps surae muscles following serial casting to correct spastic equinovarus deformity. Brain Injury. 2003b;17(4):309-24.</td>
<td>Complicated design using pooled data RCT N = 10 (n=5 originally enrolled in BTXA versus serial casting, n=5 serial casting only) 3F, 7M Age 18-48 ABI – trauma, ICH, SAH or post removal of cerebral tumour 2-10 mths post injury Australia – rehabilitation unit</td>
<td>Serial casting + botulinum toxin A (final cast bivalve to use as splint) + individualised therapy programme Dose – mean casting period 5/52 (changed weekly)</td>
<td>Serial casting + individualised therapy programme</td>
<td>Pre, initial, mid, end, post (3/12 follow up) PROM ankle – knee extended &amp; flexed – goniometer Passive resistive torque – ankle dynamometry Soleus stretch reflex onset – surface EMG</td>
<td>No difference in groups so data pooled. Casting stopped in 1 as did not achieve gains after 3 casts. Median improvements DF with knee flexed &amp; extended 30° and 15° respectively (p &lt; 0.0001) Passive resistive torque increased 4.3° p&lt; 0.0001 Maintained ROM at 6/12 in 8/9, used a back slab as required.</td>
<td>Grade B – moderate Downgraded from Grade A due to limitations. Largely well carried out study within design limitations. Findings indicate casting increases DF. • Small sample size • randomisation &amp; allocation concealment not •co-intervention •need longer term follow up •Need larger RCTs to further assess efficacy of casting.</td>
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<td>Verplancke D, Snape S, Salisbury CF, Jones PW, Ward AB. A randomized controlled trial of botulinum toxin on lower limb spasticity following acute acquired severe brain injury. Clinical Rehabilitation. 2005;19(2):117-25.</td>
<td>A double-blind placebo- RCT of three parallel treatments for lower limb spasticity Brain injury N= 35 UK Median 10 days post insult</td>
<td>Group 2: Lower leg casting plus injections with saline (group II) Group 3: Physical intervention as above, plus botulinum toxin into gastrocnemius and soleus muscles. Cast changed when 10° gain in DF.</td>
<td>Group 1: Current (normal practice) physical treatment</td>
<td>Limit of ankle dorsiflexion at entry and exit after 12 weeks. Glasgow Outcome Scale (GOS) Modified Ashworth Scale (MAS).</td>
<td>Significant improvements in the MAS scores in groups 2 and 3, but not in control (group 1). No difference between Groups 2 and 3. Cast and botulinum toxin patients also demonstrated a significant improvement in the GOS. Cast &amp; botulinum toxin patients demonstrated significant improvement in GOS, may suggest a confounding variable.</td>
<td>Grade B – moderate Downgraded from Grade A due to limitations • Well conducted study. • Active intervention with casting prevents talipes equinovarus deformities in patients losing ankle movement. • Casting alone was sufficient; the role of additional botulinum toxin needs further investigation, but is safe in these patients. • Botulinum toxin may have a role to play in a minority not responding to casting alone. • Cast &amp; botulinum toxin patients demonstrated significant improvement in GOS, may suggest a confounding variable.</td>
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<tr>
<td>Yasar E, Tok F, Safaz I, Balaban B, Yilmaz B, Alaca R. The efficacy of serial casting after botulinum toxin type A injection in improving equinovarus deformity in patients with chronic stroke. Brain Injury. 2010;24(5):736-9.</td>
<td>Retrospective cohort no prospective selection criteria.</td>
<td>Serial casting consisted of short leg casts applied while in the prone position, with the knee flexed to 90 degrees and the ankle dorsiflexed to maximal attainable dorsiflexion while held in the neutral hind foot position. Plus botulinum toxin</td>
<td>None</td>
<td>Goniometry (ankle dorsiflexion with full knee extension).</td>
<td>Significant improvements in ROM were identified. Significant improvements also identified in FIM gait score (p=0.014) and PRS (p=0.014).</td>
<td>Grade D – very low Downgraded from Grade C due to limitations.</td>
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<td>Stroke N=10</td>
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<td>Physician Rating Scale (PRS) (knee, foot contact and change scores)</td>
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<td>- Significant bias in study as retrospective nature &amp; used change scores.</td>
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<td>Mean age 33.2</td>
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<td>Functional Independence Measurement (FIM) (gait scores).</td>
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<td>- Results indicate that serial casting may be an appropriate intervention following BoNT-A injection to prevent equinovarus deformity and improve the quality of walking in chronic stroke patients.</td>
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<td>Mean 35 months ±15.3 post insult</td>
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<td>- Due to the degree of bias in this study, it should not be used to inform practice.</td>
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<td>Turkey</td>
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<td>- Possibly inappropriate to use change scores in this analysis, but the primary p values were valid.</td>
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### 7b) Evidence Tables of critically appraised systematic reviews

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<tr>
<td>Hellweg S, Johannes S. Physiotherapy after traumatic brain injury: a systematic review of the literature. Brain Injury. 2008;22(5):365-73.</td>
<td>Systematic review of different aspects of physiotherapy intervention with a specific sub-section identified for casting and splinting 14 studies fulfilled inclusion criteria of review (N= 2 Cochrane Reviews, N= 2 systematic reviews, N=8 RCTs, N=2 controlled trials) of which 5 = serial casting or splinting Acquired brain injury Switzerland</td>
<td>Serial casting or splinting (including botulinum toxin) Two systematic reviews (Watson 2001, Mortenson 2003) Three randomized controlled studies (Moseley 1997; n=9, Verplancke 2005; n=35, Lannin 2003; n=28)</td>
<td>Control groups used.</td>
<td>Main measures in the relevant studies: Range of movement Modified Ashworth Scale</td>
<td>(GRADE criteria used in this systematic review below) Recommendation grade B: Improvement in PROM after serial casts or orthosis Recommendation grade C: Reduced spasticity after serial casts or orthosis Recommendation grade A: No verifiable clinical improvement after night splints in functional position</td>
<td>Grade B –moderate. Downgraded from Grade A due to limitations: • Review mostly well conducted • Methodological assessment of papers but not clear if more than one assessor • Limited summary of papers • Recommendations should be considered related to the review of specific studies in the current work. • Final recommendation requires caveat that changes over long periods of time in specified patients may be possible (particularly related to casting) &amp; needs testing.</td>
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<td>Katalinic OM, Harvey LA, Herbert RD.</td>
<td>Systematic review (Cochrane review) with meta-analysis N=812 Varied neurological conditions e.g. stroke, TBI etc Australia</td>
<td>Joint stretch for treatment or prevention of contracture or standard care in most studies.</td>
<td>Usual care or no intervention</td>
<td>1) Joint range of movement (degrees). a) Immediate effects b) Short term effects c) Long term effects 2) Quality of life. 3) Pain.</td>
<td>Results not statistically significant for any outcome evaluation area. Stretch does not have clinically important effects on joint mobility in people with, or at risk of, contractures if performed for less than seven months. The effects of stretch performed for periods longer than seven months have not been investigated.</td>
<td>GRADE A- high • This review is well conceived and conducted with robust evaluations applied. • However, combination of prevention and reversal in the evaluation, different interventions and different doses may all have contributed to some confounding of the findings. • Stretch likely as part of usual care.</td>
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<td>Source</td>
<td>Design and participants (N) (including location and recruitment)</td>
<td>Intervention</td>
<td>Comparison (if applicable)</td>
<td>Outcome Measure/s</td>
<td>Results</td>
<td>Risk of bias, quality, grade and comment, (including limitations)</td>
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<td>Katalinic Owen M, Harvey Lisa A, Herbert Robert D, Moseley Anne M, Lannin Natasha A, Schurr K. Stretch for the treatment and prevention of contractures. Cochrane Database of Systematic Reviews [Internet]. 2010; (9).</td>
<td>Systematic review (Cochrane review) with meta-analysis N=1391 Variety of neurological and musculoskeletal conditions Australia</td>
<td>Joint stretch for treatment or prevention of contracture or standard care in most studies. Usual care or no intervention</td>
<td>1) Joint range of movement (degrees). a) Immediate effects b) Short term effects c) Long term effects 2) Quality of life. 3) Pain.</td>
<td>Results not statistically significant for any outcome evaluation area. (see above)</td>
<td>Grade A – high • This review is well conceived and conducted with robust evaluations applied. • However, combination of prevention and reversal in the evaluation, different interventions and different doses may all have contributed to some confounding of the findings.</td>
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N= 19 studies, n= 230 people. Most studies case series design (n=12; 63%), only 4 (21%) RCTs.  
Post stroke adults  
Australia | Splinting for upper limb | Various | Function of hand  
Range of movement  
Tone  
Spasticity  
Oedema  
Pain | No significant difference in motor function or contracture formation (not all OMs commented upon) | Grade B– moderate.  
Downgraded from Grade A due to limitations:  
Well conducted review. More than 3 databases used, reference lists searched, methodological quality assessed with PEDro scale.  
Most studies poor methodological quality (mostly case series).  
Insufficient evidence to support or refute the effectiveness of hand splinting for adults following stroke. |
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<th>Source</th>
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<th>Results</th>
<th>Risk of bias, quality, grade and comment, including limitations</th>
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<tr>
<td>Lannin NA, Novak I, Cusick A. A systematic review of upper extremity casting for children and adults with central nervous system motor disorders. Clinical Rehabilitation. 2007b;21(11):963-76.</td>
<td>Systematic review Adults and children – TBI, stroke and CP 11 paeds papers 1 paeds (n=153) &amp; adults (n=184) 7 adult papers (2 = case studies) 3 RCTs, 4 systematic reviews, 9 studies lower level evidence Australia</td>
<td>Upper limb casting (casting defined as non-removal, external device made from plaster or casting tape.)</td>
<td>Various</td>
<td>Range of movement Tone Pain Oedema Spasticity in elbow, wrist or hand</td>
<td>High variability in casting protocols, little consistency or consensus in practice. Identifies clinical indicators to cast in adults: soft tissue contracture, presence of spasticity, limitation in active range of movement, not being able to make a splint, prevention of contracture.</td>
<td>Grade B – moderate. Downgraded from A due to limitations: Well conducted systematic review, 2 reviewers, PEDro quality assessment, relevant databases searched, most papers low quality evidence. Insufficient evidence to either support or refute effectiveness of upper limb casting in the treatment of adults following TBI or stroke (and children with CP). No evidence of long term benefits or long term adverse effects.</td>
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<td>Mortenson PA, Eng</td>
<td>Systematic review</td>
<td>Casts were</td>
<td>Overall, the results were poor. Ten</td>
<td>Passive Range of (GRADE criteria used in this)</td>
<td>Grade B – moderate</td>
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<tr>
<th>Study</th>
<th>N= 13 studies</th>
<th>Traumatic Brain Injury (N= 9 studies)</th>
<th>Both TBI or Stroke (2 studies)</th>
<th>TBI, Stroke, cerebral hypoxia, cerebral ischemia and other (1 study)</th>
<th>Case report cerebral aneurysm</th>
<th>Canada</th>
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applied to the ankle plantar flexors in 10 studies, the elbow flexors in 5 studies, the knee flexors in 3 studies, the wrist flexors in 2 studies and the combined ankle plantar flexors and knee flexors in 1 study.

Total wearing times varied from 1 to 4 days, with the exception of a mean of 102 days in the study by Kent et al.39

Of the 10 studies on ankle casts, 4 studies had subjects bear weight (standing and walking) through the casts.

studies fulfilled 3 or less of modified Sackett’s 7 criteria demonstrating the rigor of the study. Two studies met 4 of the criteria, and 1 study met 5.

Movement (PROM) Torque-controlled PROM Goniometry and electro goniometry. 3 point scale of function Spasticity a) joint angle b) rapid movement

Holden Functional Ambulation Classification H-reflex Four point scale of spasticity (Modified Ashworth)

systematic review below)

Recommended Grade C: recommendation for use of casts in reducing spasticity after brain injury.

Recommended Grade B: recommendation use of casts in improving PROM or preventing loss of PROM that results from complications of brain injury & subsequent spasticity.

Improvement in function cannot be supported. Further evaluation with appropriate measurement methods needed.

Downgraded from Grade A due to limitations:

- Robust systematic review. It was not possible to perform meta-analysis.
- Low level evidence in most papers included in review
- Functional evaluation is needed, but will require a robust measure of function adhering to the ICF levels
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<tr>
<td>Tolfts A, Stiller K. Do patients with traumatic brain injury benefit from physiotherapy? A review of the evidence. Physiotherapy Theory &amp; Practice. 1997;13(3):197-206.</td>
<td>Systematic narrative review of experimental designs (pre-Cochrane) Medline &amp; Cinahl and reference lists searched N= 10 studies (3x case studies), 123 participants with TBI (serial casting – 6 papers; single applications Time post injury 2 days to 13 months Authors Australian – various papers</td>
<td>Casting – below knee, long leg, elbow Splints Dose – 2 hours to 7.5 months</td>
<td>n/a</td>
<td>Range of movement Tone (plus others not relevant to guidelines)</td>
<td>Range increase from 10 to 93° from splinting/casting No specific results on effect on tone</td>
<td>Grade C - low • no assessment of methodological quality Small sample size • Inherent biases in individual study designs e.g. no control group, not randomised • co-interventions • need longer term follow up Review of evidence suggests casting or splinting may be effective in improving restricted range of movement after TBI. Weaknesses in individual studies reduce confidence in the results.</td>
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<tr>
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<td>Tyson S, Kent R. The effect of upper limb orthotics after stroke: a systematic review. NeuroRehabilitation. 2011;28(1):29-36.</td>
<td>Systematic review &amp; meta-analysis RCTs only N=4, 126 participants Sample sizes 12 to 42, most based on power calculations Stroke &amp; other non-progressive brain lesions Authors – UK, studies various.</td>
<td>Splints/orthoses (not serial casting) – custom made thermoplastic splints applied to wrist, fingers and or thumb Dose: 12 hours overnight; 6 hours during the day; for 4-13 weeks.</td>
<td>No treatment or usual care</td>
<td>Upper limb impairments Function Disability</td>
<td>Confidence intervals mixed, spanned zero &amp; overall effect sizes not significant. Disability: MD = 0.37 points; (95%CI, -0.19 to 0.93, P= 0.2). Impairment: MD = 0.04° (95%CI, -5.21 to 5.30 P=0.99) Pain – 1 study found significant lower incidence of wrist pain with use of orthosis (1/15 vs 8/15, p=0.004)</td>
<td>Grade A – high. Well conducted study • all key databases searched, follow up of reference lists • excluded non-English papers • need longer term follow up • Multiple studies by the same research team so conclusions should be treated with caution. Findings suggest UL orthosis does not effect function, ROM at wrist, fingers or thumb, nor pain.</td>
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Appendix 8: Abbreviations

Abd  abduction
ABI  Aquired brain injury
ACPIN  Association of Chartered Physiotherapists in Neurology
AFD  Ankle dorsiflexion dynasplint
AFO  Ankle foot orthosis
AMED  Allied and complementary medicine
ANOVA  Analysis of variance
ARAT  Action research arm test
ArmA  Arm activity measure
A-ROM  Active range of movement
AVM  Arterio venous malformation
Ax  Assessment
BMJ  British medical journal
BoNT-A  Botulinum toxin type A
BTA  Botulinum toxin type A
BTX  Botulinum toxin
CASP  Critical appraisal skills programme
CI  Confidence interval
CK  Cherry Kilbride
Clin Rehabi  Clinical Rehabilitation
CME  Carpo metacarpal joint
CNS  Central nervous system
COT SS-NP  College of Occupational Therapist Specialist Section Neurology Practice
CP  Cerebral palsy
CSP  Chartered Society of Physiotherapy
CVA  Cerebro vascular accident
DASH  Disabilities of the arm shoulder and hand outcome measure
DF  Dorsiflexion
DIP  Distal interphalangeal joint
DORIS  Database of research in stroke
DS  Dorsal splint
EMG  Electromyography
Expt  Experiment
Ext  Extension
F  Female
F/U  Follow up
FAC  Functional ambulation categories
FES  Functional electrical stimulation
FIM  Functional independence measure
FMA  Fugl Meyer Assessment
GAS  Goal attainment scaling
Gastroc  Gastrocnemius muscle
GCS  Glasgow coma scale
GOS  Glasgow outcome scale
GRADE  Grading of Recommendations Assessment, Development and Evaluation
HCPC  Health and care professions council
References – please note this section is still being worked upon during consultation, so references may be missing at this stage. Apologies.


Cormack, J. and Powers, C. M. (2004) 'Is there evidence that botulinum toxin injections are more effective than phenol injections in relieving poststroke reflex activity during plantar flexion, thereby increasing ankle range of motion and improving gait function?', *Physical Therapy (PHYS THER)*, 76-84.


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Yelnik, A. P., Colle, F. M. C. and Bonan, I. V. (2003b) 'Treatment of pain and limited movement of the shoulder in hemiplegic patients with Botulinum toxin A in the subscapular muscle', European Neurology, 50, 91-93.


