Upper Limb Orthoses (Splinting) in children with cerebral palsy

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Transitional therapy

Infants & pre-school (0-4yo)

- Environmental enrichment
- Constraint-induced movement therapy
- Bimanual therapy

School readiness – Goal directed training

Primary school (5-12yo)

- Goal directed training
- Pathways and Resources for Engagement and Participation (PREP)

Adolescence (12-18yo)

- Goal directed training
- Pathways and Resources for Engagement and Participation (PREP)
- Transition support

Botulinum toxin-A

Static night upper limb orthoses

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"Children with disabilities may not do things nicely and 'normally' but they are still making developmental progress. I think there's more than one path to success. And I would strongly encourage all of us to enable and support children to do things in whatever ways they can. Because the more they do, the more they practice. The more they practice, the better they get at it. If they never do it beautifully, that's, to me, not a big problem".

Professor Peter Rosenbaum.

Clinical perspectives on orthoses

- In the absence of evidence that supports or refutes the use of static upper limb orthoses.
  - Why not?
- We understand the natural history of increasing upper limb impairment in children with cerebral palsy.
  - Why wait?
- Static wrist/hand orthoses should provide a stretch into a position that is not actively achieved during functional limb use.
  - Why "resting position"?
- Consistent with all impairment-based interventions, static wrist/hand orthoses should be viewed as an adjunct to evidence-based upper limb therapy.

Outline

- Muscle overactivity in children with CP.
  - Are we speaking the same language?
- Aims of static wrist/hand upper limb orthoses.
  - Main focus on children at MACS levels I to III.
- Evidence for static upper limb orthoses in children with CP.
- What type of orthosis to prescribe?
  - Position.
  - Materials and fabrication.
  - Wearing regime and compliance.

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Are we speaking the same language?

- "Tonus" - The slight contractile tension of muscles when at rest (Mueller, 1838).
  - The term "tonus" became ingrained in the literature.
- Although clinicians often studied two signs.
  - Posture.
  - Resistance to passive displacement.
- Which is made up of:
  - Joint and muscle resistance.
  - The stretch reflex.

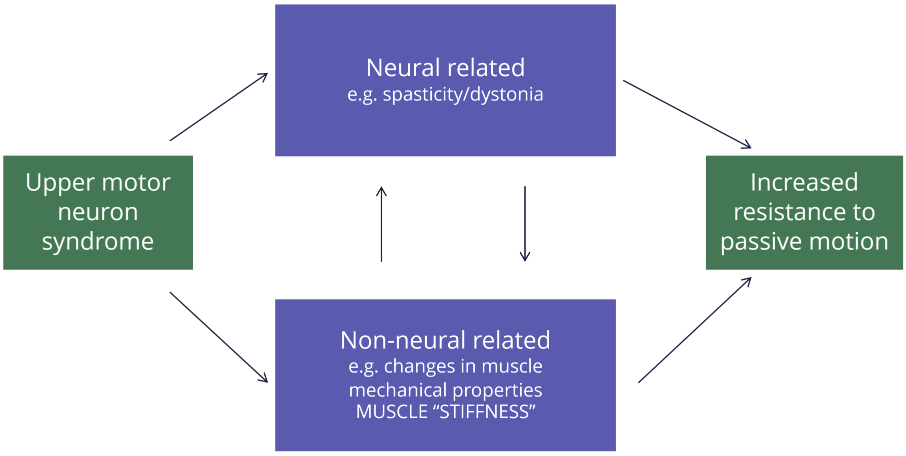
Rushworth, 1960

Impact of early brain lesion on muscle

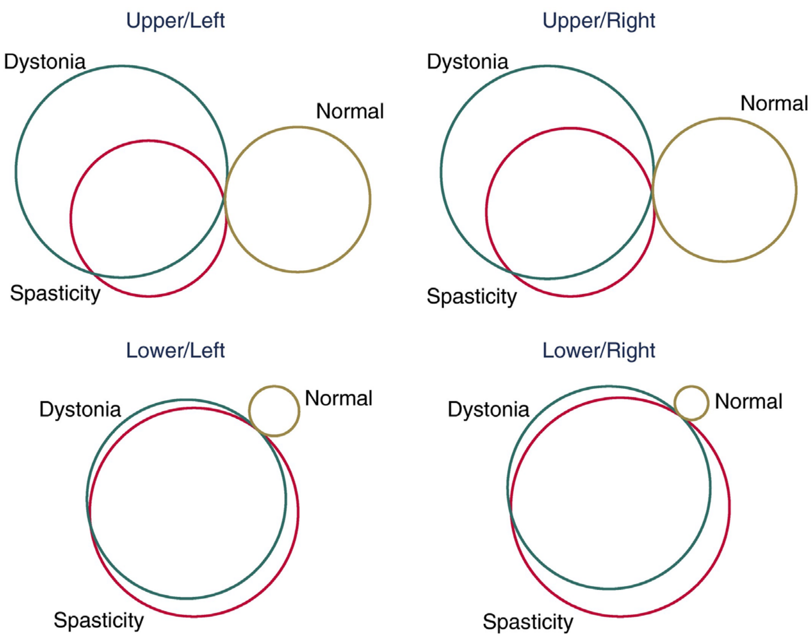
- Muscle overactivity (spasticity and dystonia).
  - Spasticity - Increase in velocity-dependent stretch reflex.
  - Dystonia - Involuntary sustained or intermittent muscle contractions cause twisting and repetitive movements, abnormal postures or both (Sanger, 2003).
- Changes in muscle and soft tissue mechanical properties (muscle stiffness).
  - Loss of passive ROM (contracture).
- Muscle weakness (paresis).

Yelnik, 2010

Increased resistance to PROM



Bar-on, 2015



Rice, 2017

Dystonia

- A spastic catch may not be present (Jethwa, 2010).
- Results in abnormal postures at rest and/or during voluntary muscle movement.
  - Severe dystonia - deforms joints and body postures.
  - "Subtle" dystonia – influences posture and motor control.
- Results in limited active range of motion during functional limb use.
  - Muscles immobilised in a shortened position.
- **What we see during active, purposeful upper limb movement is much more important than what we feel.**

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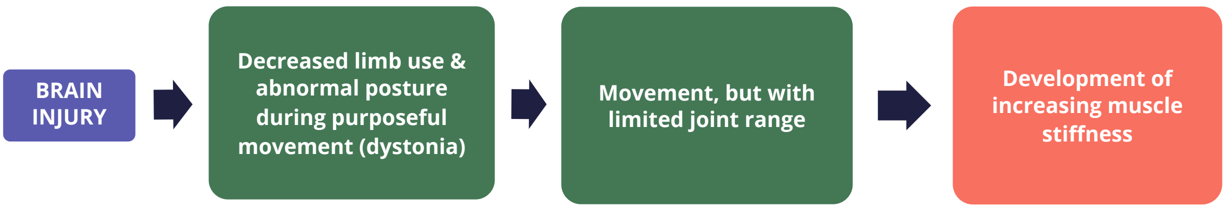

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Muscle overactivity

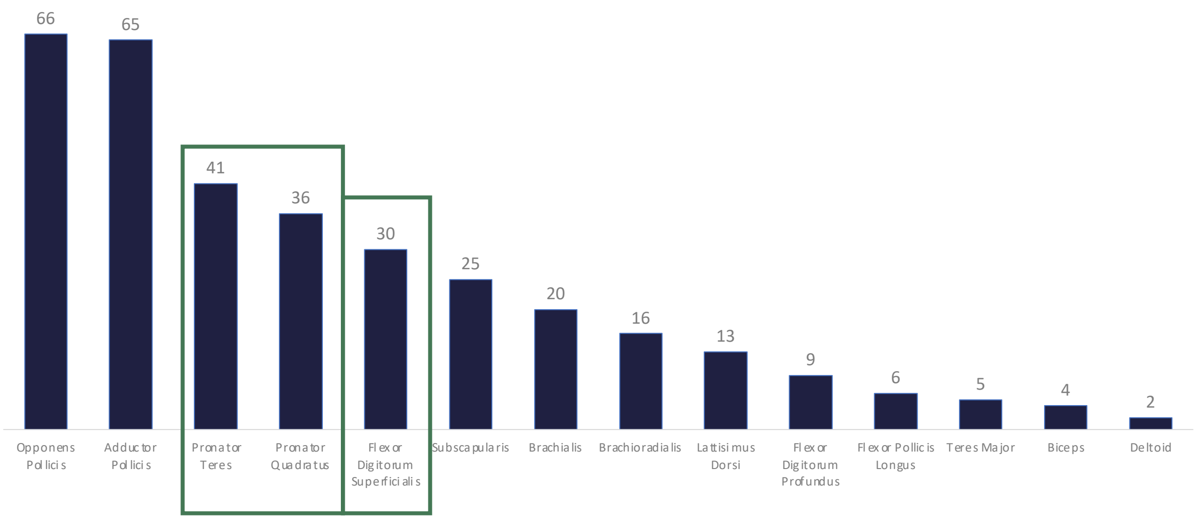
- In growing children, lengthening of a muscle is stimulated by growth of bone and by muscle excursion (Nordmark, 2009).
- Overactivity and immobilisation in a shortened position leads to failure of muscle growth (Delp, 2003, Nordmark, 2009).
- Prolonged activation due to spasticity will cause fiber shortening resulting in stiffer muscles (Bar-On, 2015).
- These changes lead to the development of increased resistance to stretch (**muscle stiffness**) and in some children, restricted range of motion (**contracture)** (Gracies, 2005).

Development of upper limb contracture

- 34% developed upper-limb contracture.
  - The first affected movements were wrist extension (with fingers extended) and forearm supination.
- Once contracture development starts, it is hard to stop it.

Hedberg-Graff, 2018

BoNT-A injections for children <2yo



Prevention or salvage?

- In the children who developed contractures.
  - The decrease in PROM started during the first years of life (Hedberg-Graff, 2018)
  - Should we wait?
- Knowledge of increasing impairment warrants preventive care to avert the development of stiffness in muscles known to be at risk (Hagglund, 2008; Nordmark, 2009; Arner, 2008).
  - Use timely interventions to mitigate the natural history of increasing deformity.
- Salvage Surgery - After the horse has bolted.... (Thomason, 2014).
  - A dysplastic, dislocated hip is a disaster!....but the options for managing it are not much better! (Thomason, 2014).
  - What about the upper limb?

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Aims for static wrist/hand orthoses

- Provide a prolonged, low load stretch aiming to reduce muscle stiffness, improve ease and control of movement and ultimately, prevent muscle contracture.
- Maintain/increase passive and active range of motion.
- Prevent development of, or reduce, abnormal postures during active movement of the upper limb.

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Upper limb orthoses: Acute adult ABI

- Effects are statistically non-significant and clinically unimportant.
  - "An overnight splint-wearing regimen in the functional position does not produce clinically beneficial effects".
- Neither splint appreciably increased extensibility of the wrist and long finger flexor muscles.
  - "Splinting of the wrist in either the neutral or extended wrist position for 4 weeks did not reduce wrist contracture after stroke".
  - "These findings suggest that the practice of routine splinting to prevent muscle contracture soon after stroke should be discontinued".

Lannin 2003 & 2007

2017 Stretch Cochrane Review

- 49 studies with 2135 participants.
  - 5 studies included children
    - 4 studies of children with CP
      - 3 lower limb casting
      - 1 hand splint (Krumlinde-Sundholm, 2010)
  - Passive stretch, splinting, positioning, or serial casting for any age or diagnosis to treat or prevent contractures.
- No study performed stretch for more than 7 months.

Harvey, 2017

treatment (CIMT) group with decreased maximum shoulder displacement. This indicated that more individuated control of the involved upper extremity developed when the non-involved hand was restrained (less trunk movement) during treatment. The results support our hypothesis of specificity of practice.

E4
Hand splints in children with cerebral palsy: effects of maintained or disrupted use

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Background/Objectives: In children with cerebral palsy (CP) an associated progressive musculoskeletal pathology may cause problems with joint alignment and contractures leading to functional limitations. Hand splints are often used clinically with the aims to improve, maintain or prevent shortening of soft tissue length. However, little is known about the effects of hand splints. The objective of this study was to evaluate whether stretching splints worn overnight had an effect on passive range of motion (PROM) for wrist extension or thumb abduction.
Design: A crossover design was utilized. Children already using splints were randomized into one of two groups: 6 months without a hand splint or 6 months of continued hand splint use. After the 6 months groups were crossed over for another 6 months.
Participants and Setting: Sixty three children diagnosed with cerebral palsy and listed as clients in the hand clinic within the Children's Rehabilitation services in the Uppsala region, Sweden, were invited to participate in this study. Thirty-seven agreed to participate. During the 12 month trial period 11 dropped out leaving 26 children. Mean age was 9.5 years (range 1–16). Twelve children had unilateral CP and 14 bilateral. Children were classified across all MACS and GMFCS levels.
Materials/Methods: Measures of PROM were obtained by goniometry every 3rd month during the course of 12 months, by the same occupational therapist, blinded to group allocation. A questionnaire about the actual use of the splints and stretching regimes was completed. Criteria were established for how much deterioration was acceptable before interrupting a no-splinting protocol. Effects on PROM of the wrist (27 hands) and the thumb (28 hands) were analyzed with Repeated measures ANOVA.
Results: For the wrist a significant deterioration of PROM was found during the no-splint period after 3 months from baseline (dif −6.66, p=0.003) and after 6 months (dif −6.85, p=0.002). After 3 months, two children (four hands) had deteriorated more than the pre-defined criteria and splint use was re-established. During the splint wearing period a significant increase of PROM was seen at 3 months (dif 4.07, p=0.030) and at 6 months (dif 5.18, p=0.006). For thumb abduction, a deterioration was seen after the no-splint period of 3 months (dif −4.10, p=0.003). For three children splint use was re-established due to the level of deterioration. For the remaining children at 6 months the PROM had further declined (dif −2.70, p=0. 016). During the splint use period thumb abduction was stable over time.
Conclusions/Significance: For a group of children who regularly used overnight hand stretching splints, interrupted use resulted in decreased PROM. However, several children who had near full ROM at baseline did not demonstrate deterioration from 6 months of no-splint use. For them, hand splints were not required for contracture prevention. The clinical significance of these findings warrant further investigation.

E5
Constraint-Induced Movement Therapy versus equally intensive bimanual training for children with central hemiparesis: a comparative study

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Background/Objectives: The efficacy of Constraint-Induced Movement Therapy (CIMT) in children with cerebral palsy has been proven in several studies (Taub et al, Pediatrics 2004, Eliasson et al, Dev Med Child Neurol 2005, Charles et al, Dev Med Child Neurol 2006). Yet it is unclear what the main principles of efficacy are - restraint, structured therapy or high therapy intensity? To clarify the importance of hand-arm restriction we have developed an equally intensive well-structured bimanual program and compare it with our child-friendly interdisciplinary kid-CIMT program.
Design: Prospective, randomized, controlled intervention study.
Participants and Setting: Children with unilateral cerebral palsy or other lasting hemiparesis after non-progressive brain injury, aged 3.0 to 12.0 years. Selection criteria: independently walking, at least some limited active movements of shoulder, elbow and wrist, no severe mental retardation, no attention deficit.
Setting: Six weeks of in-patient rehabilitation in a rehabilitation centre with interdisciplinary approach.
Sample: Forty-eight children were included, six had to be secondarily excluded. From the remaining 42 patients 24

Krumlinde-Sundholm, 2010

Efficacy of hand splinting

- N = 37 (11 drop-outs leaving) leaving 26 children. Mean age 9.5 years (range 1–16),12 unilateral,14 bilateral. Across all MACS and GMFCS levels.
- 6 months with or without a static hand splint at night.
- For a group of children who regularly used overnight hand stretching splints, interrupted use resulted in decreased PROM.
- Several children who had near full PROM at baseline did not demonstrate deterioration from 6 months of no-splint use.

Krumlinde-Sundholm, 2010

DEVELOPMENTAL MEDICINE & CHILD NEUROLOGY OPINION

The evidence for abandoning upper limb stretch interventions in paediatric practice

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Katalinic et al.[1] have published a methodologically rigorous Cochrane systematic review of the effectiveness of stretch interventions for the treatment and prevention of contractures. Paediatric practitioners must evaluate how to translate the evidence from this review into practice as the review provides persuasive evidence that continued use of stretch interventions needs careful consideration. The outcomes and the quality of this comprehensive review are not in dispute. We believe, however, that it provides insufficient evidence to warrant abandoning upper limb stretch interventions in children.

Eligible studies included those evaluating sustained passive stretch, splinting, positioning, or serial casting used with study participants of any age or diagnosis to treat or prevent contractures. The review concluded there was little or no effect of stretch interventions on range of motion in people with neurological conditions. Insufficient evidence existed for stretch interventions in other diagnostic groups or effects of stretch intervention on other outcomes of interest, such as pain, spasticity, activity limitation, participation restriction, or quality of life. These results were consistent across several planned subgroup analyses completed to determine if stretch had differential effects according to, amongst other variables, diagnosis, dosage and different joints. Perhaps out of consideration for multiplicity effects, subgroup analyses were not conducted for age of study participants or interventions applied to the upper limb versus lower limb. Results of such subgroup analyses may have provided us with additional information to guide our response to this review.

Only five of the 35 randomized trials included in Katalinic et al.'s[1] review included children. Differences exist between adults and children which mitigate against generalizing the effectiveness of stretch interventions in adults to children. One difference is the effect of growth: adults have reached skeletal maturity whereas children continue to alter with respect to bone, muscle, and connective tissue growth and development.

Of the five paediatric studies in Katalinic et al.'s review, only one was of upper limb stretch intervention and the participants in this study had cerebral palsy (CP).[2] One study of children with CP using a single protocol for one stretch intervention is simply insufficient justification to extrapolate results to upper limb management in all paediatric diagnoses. Differences in fibre type, extracellular matrix and myogenesis between wrist muscles of children with CP and typically developing controls have been identified.[3] Furthermore, the unique transcriptional profile of muscles in children with CP is different again to other disorders such as Duchenne muscular dystrophy.[3] The underlying cause of contracture in children with arthrogryposis (multiple congenital contractures), which is associated with many different conditions, may be neurological in origin or due to muscle, connective tissue, or maternal factors, amongst others.[4] Different fundamental aetiology suggests that stretch interventions may need to be unique for different diagnostic groups and reinforces our reluctance to m[illegible] universal decisions regarding stretch interventions fo[illegible] upper limb in children generally, based on a single pa[illegible] upper limb study.

We firmly believe it is imprudent to abandon [illegible] stretch interventions in paediatric practice. Sim[illegible] were drawn by Lannin et al.[5] in their syst[illegible] upper limb casting for children and adults [illegible]vous system disorders. They urged further [illegible]omogeneous protocols of casting based on [illegible]ical rationales. Consideration may need to [illegible]e complexity of many paediatric caseloads wh[illegible]nterventions and selecting outcomes. Importa[illegible]s include delaying, avoiding or maintaining ou[illegible] surgery, reducing caregiver burden, promoting [illegible]nd complementary effects of supplementing inter[illegible]uch as botulinum toxin injections with stretch in[illegible]ns. Relevant outcomes measures, therefore, may i[illegible] those that are individualized and family-focussed[illegible]

Katalinic e[illegible] thought-provoking review provides impetus to criti[illegible]evaluate the ongoing use of upper limb stretch interven[illegible] across a range of paediatric diagnoses. Practitioners s[illegible]d continue to educate families regarding the current stat[illegible] the evidence as well as potential benefits and inconven[illegible]ces of stretch interventions – enriched by our clinical reasoning and experience – to assist in making decisions about stretch as a treatment option. In the absence of definitive evidence, we are also obligated to closely monitor and document the outcomes of stretch interventions with individual children – for example, that range of motion increases and goals established for intervention are attained. We should also examine all levels of evidence and theoretical rationales in the area to inform study protocol development, and conduct methodologically rigorous research to evaluate the outcomes of upper limb stretch interventions in children with different neurological and non-neurological conditions.

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Children continue to alter with respect to bone, muscle, and connective tissue growth and development

It is imprudent to abandon upper limb stretch interventions in paediatric practice

Wallen, 2013

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Imms et al. *BMC Pediatrics* (2016) 16:70
DOI 10.1186/s12887-016-0608-8

BMC Pediatrics

STUDY PROTOCOL Open Access

Minimising impairment: Protocol for a multicentre randomised controlled trial of upper limb orthoses for children with cerebral palsy

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Abstract

Background: Upper limb orthoses are frequently prescribed for children with cerebral palsy (CP) who have muscle overactivity predominantly due to spasticity, with little evidence of long-term effectiveness. Clinical consensus is that orthoses help to preserve range of movement: nevertheless, they can be complex to construct, expensive, uncomfortable and require commitment from parents and children to wear. This protocol paper describes a randomised controlled trial to evaluate whether long-term use of rigid wrist/hand orthoses (WHO) in children with CP, combined with usual multidisciplinary care, can prevent or reduce musculoskeletal impairments, including muscle stiffness/tone and loss of movement range, compared to usual multidisciplinary care alone.

Methods/design: This pragmatic, multicentre, assessor-blinded randomised controlled trial with economic analysis will recruit 194 children with CP, aged 5–15 years, who present with flexor muscle stiffness of the wrist and/or fingers/thumb (Modified Ashworth Scale score ≥1). Children, recruited from treatment centres in Victoria, New South Wales and Western Australia, will be randomised to groups (1:1 allocation) using concealed procedures. All children will receive care typically provided by their treating organisation. The treatment group will receive a custom-made serially adjustable rigid WHO, prescribed for 6 h nightly (or daily) to wear for 3 years. An application developed for mobile devices will monitor WHO wearing time and adverse events. The control group will not receive a WHO, and will cease wearing one if previously prescribed. Outcomes will be measured 6 monthly over a period of 3 years. The primary outcome is passive range of wrist extension, measured with fingers extended using a goniometer at 3 years. Secondary outcomes include muscle stiffness, spasticity, pain, grip strength and hand deformity. Activity, participation, quality of life, cost and cost-effectiveness will also be assessed.

Discussion: This study will provide evidence to inform clinicians, services, funding agencies and parents/carers of children with CP whether the provision of a rigid WHO to reduce upper limb impairment, in combination with usual multidisciplinary care, is worth the effort and costs.

Trial registration: ANZ Clinical Trials Registry: U1111-1164-0572.

Keywords: Upper extremity, Splint, Orthosis, Children, Cerebral palsy, Occupational therapy, Intervention, Randomised trial, Cost-effectiveness

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Imms, 2016

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iWHO & Minimising Impairment RCTs

- **Aim:** To evaluate the efficacy of medium to long-term use of rigid wrist/hand orthoses in children with cerebral palsy.
- Two multi-centre RCTs of rigid wrist/hand orthoses (WHO) in children with cerebral palsy.
  - Study 1 – children < 3 years old
  - Study 2 – children 6 to 15 years (stopped)
- **Intervention Group:** Custom-made serially adjustable rigid WHO for minimum 6 hours/day or night for 3 years.
- **Control Group:** No rigid WHO.
- **Both Groups:** continue usual treatment.

Equity Trustees ACU murdoch children's research institute iWHO Trial Curtin University

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Jackman, 2014

Garbellini, 2017

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Efficacy of hand splinting

- 6 RCTs (cast, brace, or orthosis)
  - 1 functional splint
  - 5 non-functional splints
- A small trend favoring splint plus therapy over therapy-alone, based on moderate-quality evidence
- No evidence to support the use of upper limb hand splints for children with CP in isolation

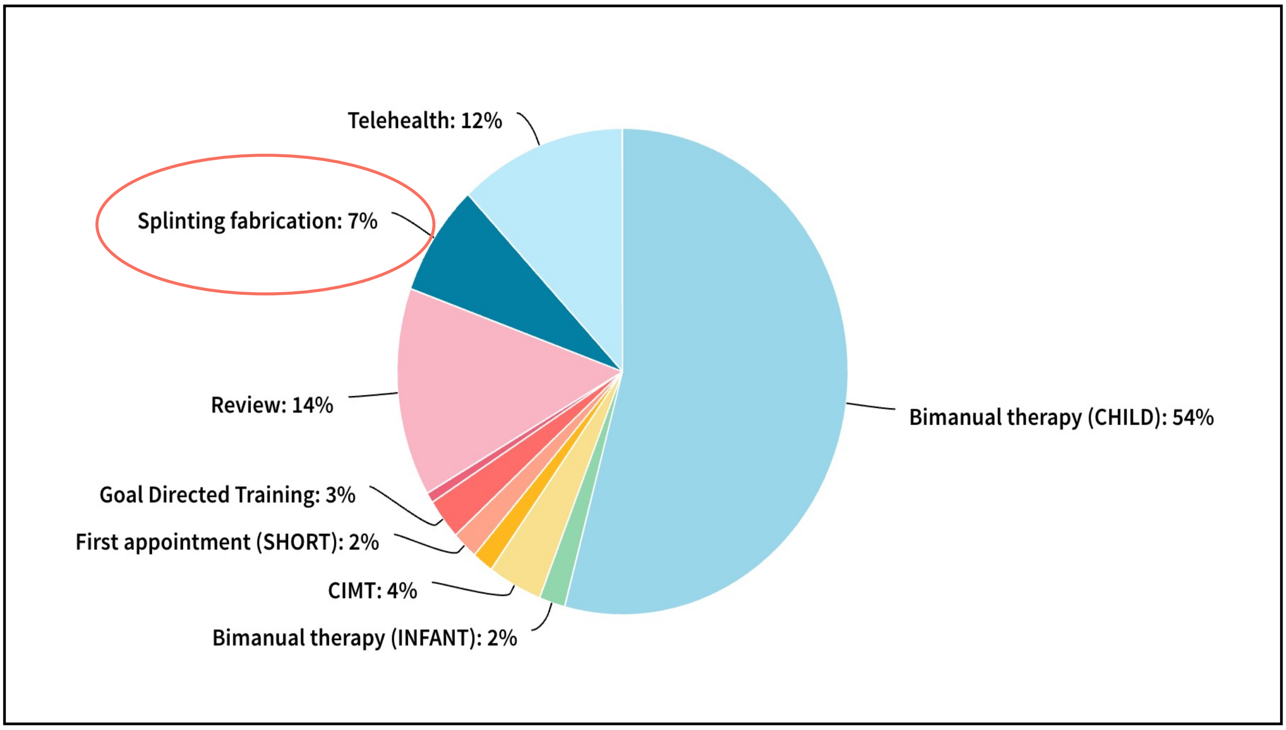
Jackman, 2014

EBM's six dangerous words

- **"There is no evidence to suggest"** (Braithwaite, 2013).
  - that upper limb static wrist/hand orthoses are effective

    EQUALLY

  - that static wrist/hand orthoses are ineffective (or harmful) for children with CP
- "Until evidence has been established, it is considered the potential benefits of sustained stretch overnight when a child is not using the limb(s) far outweigh the negligible risks and low cost of this intervention" (Hoare, 2014).


Telehealth: 12%
Splinting fabrication: 7%
Review: 14%
Goal Directed Training: 3%
First appointment (SHORT): 2%
CIMT: 4%
Bimanual therapy (INFANT): 2%
Bimanual therapy (CHILD): 54%

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Clinical considerations

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Clinical indicators

- Persistent abnormal flexion postures of the wrist +/- fingers +/- thumb during active use of the upper limb(s)

AND/OR

- Presence of flexor muscle stiffness - score of at least 1 on the Modified Ashworth Scale during passive wrist extension with fingers extended.

- May or may not already exhibit contracture.

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“My child’s hand is relaxed overnight”

- Almost all children with CP who experience muscle overactivity are relaxed overnight.
- Opportunity to take advantage of relaxed state.
- Difference between being relaxed vs. receiving stretch for 8-12 hours.

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Contraindications

- Primarily dystonic, rather than spastic motor disorder.
- The presence of child and/or family factors that identify upper limb orthoses wear as not clinically indicated.
- Allergy/sensitivity to thermoplastic material.
- Significant child refusal to comply with wearing schedule.
- Significant difficulties with sleep.

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Positioning principles

- What muscles are overactive?
- What joints are likely to become stiff and lose ROM?
- What corrective forces should be applied?

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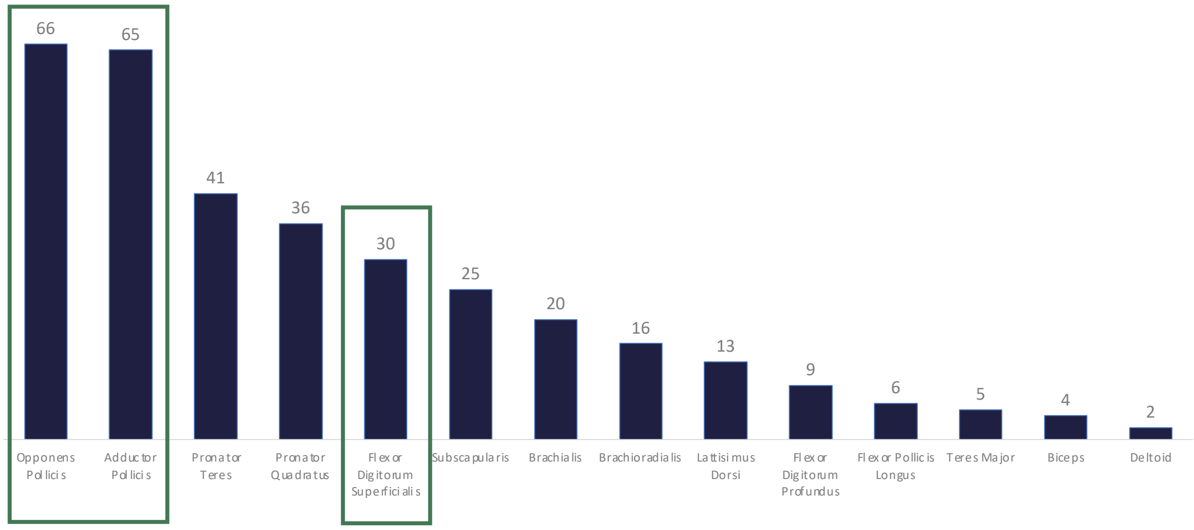
BoNT-A injections for children <2yo



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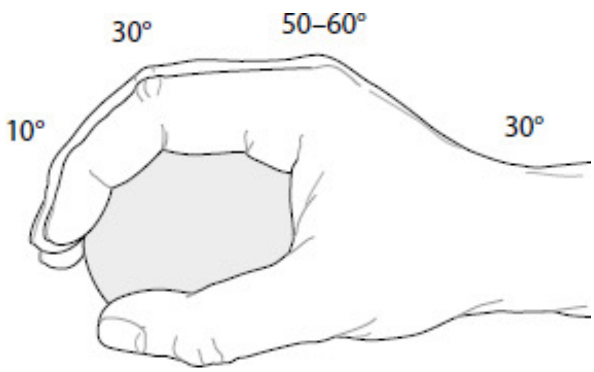
Functional position



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Positioning - Young Children

Thumb

- End range of MCP joint **extension and abduction**.
- MCP joint supported on the volar surface to avoid hyperextension.
- IP joint in neutral to slight flexion.

Wrist

- 35 º to 55 º degrees of extension (0º = neutral) and neutral ulnar/radial deviation.

Fingers

- MCP and IPs in small amount of flexion (10- 30º).

Positioning - Older Children

Correction of known and increasing deformity

- Thumb MCP and CMC joints (aim for maximum possible abduction and extension).
    - May be limited by contracture.
- Wrist extension (aim for maximum possible PROM).
    - Try to achieve neutral to slightly radially deviated position if possible.
- Fingers (MCP and IPs in small amount of flexion).
    - Do not hyperextend MCP’s

Thermoplastic material selection

Age: < 1year
- 1.6mm, Aquaplast-T 13% Ultraperf

Age: 1 to 3 years
- 3.2mm Aquaplast-T, 19% Optiperf

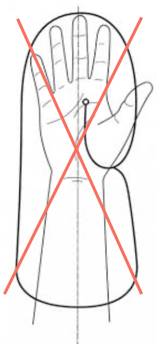
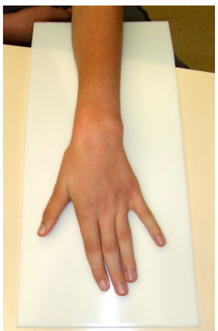
Age: 3 to 10 years
- 3.2mm San-splint, 2.5% perf

Age: 10 years +
- 3.2mm Aquaplast-T, Solid (Ball splint)




Orthosis construction

- Estimate of the size of thermoplastic. Place child's hand over the thermoplastic sheet. Mark and cut a rectangle.
- Shape to the limb, and customise to position goals.
- No pattern required.


Hypoxic hands


Hypoxic hands

- Intrinsic minus - posture of MP flexion and IP extension (Intrinsic plus).
- Typically, much greater FPL overactivity and shortening.

Positioning principles

- Focus on MCP extension.
- Aim for neutral wrist position.



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Common problem – radial drift


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Solution – finger spreaders

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Common problem - slippage

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Common problem - slippage

- Why does an orthosis slip?
  - What is happening biomechanically?
- Why is an orthosis poorly tolerated?
  - Where is most of the force applied to the wrist/hand?

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Common errors – strapping

25mm rigid loop velcro

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Solution - Strap position

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Wearing regime – What's the dose?

Intervention fidelity

- The degree to which an intervention maintains its original form (Cohen, 2008).
  - Medications don't work if not taken at the appropriate therapeutic dosage.

- No evidence to guide clinical practice
  - Contractures did not occur when lower limb muscles were stretched for more than 6 hours per day (Tardieu, 1988).

- Aim of upper limb rigid, wrist/hand orthoses is to provide a **sustained**, low load stretch to overactive muscles.
  - How long does a child sleep for?

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Encouraging orthosis use

- If a child wants to remove a splint – they will.
- Never attempt to introduce a splint when a child has poor sleep routine.
  - Support good sleep habits first.
- Conformity is essential. 99% correct fit is not acceptable.
  - Be confident to start again.
- Implement orthosis program early.
  - Part of the nightly routine.
- Coach parents on the use of positive psychology.
  - Language used.
  - No force, no threats.
- Place the orthosis on when the child is asleep.

Conclusion

- One third of children with cerebral palsy may develop upper limb contracture.
  - Who are they?
- In the absence of evidence to support or refute upper limb orthoses.
  - Why not?
  - No known harm, low cost, but significant potential benefit.
- If you implement an upper limb orthosis program, do it well.
  - Conformity, materials, behaviour support, regular reviews.
- Upper limb orthoses should always be viewed as an adjunct to evidence-based activity level therapy.

Thank you

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