The effect of serial casting on gait in children with cerebral palsy: preliminary results from a crossover trial

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Abstract

Serial casting aims to improve an equinus gait pattern in children with spastic cerebral palsy (SCP). We evaluated the effect of short-term stretch casting on gait in children with SCP, compared to the natural history. A crossover trial, consisting of a control phase and a casting phase, was conducted with children randomised into two groups. Both groups were assessed clinically, and using 3D gait analysis, at 0, 5 and 12 weeks. Subjects in one group had the 3 month casting phase first and in the other had the 3 month control period first. Casts were changed weekly and set at maximum available ankle dorsiflexion. The mean changes at 5 weeks and 12 weeks from baseline measurements in the casting phase were compared with the change within the same time interval in the control phase. Significant improvements in passive ankle dorsiflexion (knee flexed) were found at 5 and 12 weeks. Passive ankle dorsiflexion (knee extended), ankle dorsiflexion in single support, ankle dorsiflexion in swing and minimum hip flexion in stance improved significantly at 5 weeks but not at 12 weeks from baseline. Other kinematic parameters, the score on the Gillette Functional Assessment Questionnaire, and maximum reported walking distance were not changed by casting.

Casting to improve range appears to improve passive and dynamic ankle dorsiflexion, but the changes are small, short lived and do not appear to affect function.

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1. Introduction

Toe walking is a common presentation in young children with mild spastic cerebral palsy (SCP). While toe walking initially appears to be a dynamic phenomenon, secondary to an upper motor neuron lesion, as the child grows, muscle deformities, and a fixed component to the ankle equinus, may develop. The natural history in this group is one of increasing deformity and deterioration in function [1,2].

Early therapeutic intervention for children with cerebral palsy aims to facilitate the development of normal movement patterns as well as maintaining range of motion. Fixing the position of the ankle into or beyond the neutral sagittal plane position by means of a cast is one intervention employed with the aim of normalising an equinus gait pattern [3].

Serial casting is used variably to inhibit the overactivity of the ankle plantarflexors [3–15] or to lengthen components of the musculo-tendinous unit [16–24]. Typically, inhibition is thought to be achieved by maintaining the foot and ankle in a neutral position for a period of over 2 weeks. The casting period may be followed by a regime of splinting or casting for shorter periods during the day. [7,9]. Some authors have observed increases in ankle dorsiflexion secondary to inhibitive casting [11,13–15] and gait improvements have also been noted. Bertoti [10] found stride length to increase in some of a group of 10 children with CP following 10 weeks of application of bivalved casts, for more than 4 h per day. Zachazewski et al. [7] and Watt et al. [11] described a
normalisation of the foot contact pattern following casting for 3–4 weeks. Flett et al. [14] showed an improvement in the gait pattern of 10 children following serial casting using two items of the Physicians’ Rating Scale. Three-dimensional (3D) motion analysis was used by Corry et al. [13] to assess walking in five children following serial casting. In this small group of children, ankle dorsiflexion in stance and swing was shown to significantly increase, but the effects were short lived. In contrast, Ackman et al. [15] found ankle dorsiflexion to be improved in stance a year following casting and improved in swing for up to 7.5 months although casting was repeated three times during this time.

Casting aimed at lengthening the triceps surae musculature is often prescribed when a mild fixed ankle plantarflexor contracture is present [16–23]. It involves the removal and reapplication of the cast at intervals between 2 and 14 days. At each change of cast, the ankle is positioned in increased amounts of dorsiflexion, progressively stretching the calf musculature until the desired range of motion at the ankle is achieved. This method is based on the theory that muscles adapt to an imposed increase in length (for review see Gajdosik [27]).

Tardieu et al. [16], Westin and Dye [17], Brouwer et al. [20,25], Cottalorda et al. [21], Kay et al. [23] and Glanzman et al. [24], all found a significant increase in passive ankle dorsiflexion following serial casting in groups of children and adults with and without neurological conditions. Brouwer et al. [25] also suggest that there is a change in the range at which the plantarflexors are able to produce their maximum force up to 6 weeks following cast removal. Visually detected improvements in gait assessed up to 6 weeks following intervention has been shown in children with SCP [18–20]. Using 3D-gait analysis, Kay et al. [23] showed an improvement in dorsiflexion in stance and swing following prolonged serial casting in a group of 10 children. Significant improvements were apparent 12 months following casting.

Both inhibitive and stretch-casting involve immobilisation of the ankle joint in a cast while encouraging the child to walk. They also have a similar primary aim of improving the gait pattern of these children, particularly attempting to change
gait from a toe–toe pattern to a heel–toe pattern. Some authors believe the changes following casting are the result of both inhibition and structural muscle adaptation [25,26].

No controlled studies of serial casting using 3D gait analysis as an outcome measure have been performed to date. We investigated the effects of stretch serial casting on ankle dorsiflexion range and lower limb kinematics and kinetics during gait, in a group of children with SCP with mild fixed ankle plantarflexion contractures and an equinus gait pattern.

2. Method

Ethical permission for this study was given by the Local research ethics committee. Nine children with SCP (three with hemiplegia and six with diplegia) over the age of 5 years with mild fixed ankle plantarflexion contractures and in whom a clinical recommendation of serial casting to improve ankle dorsiflexion range has been made were recruited to the study. No child had received botulinum toxin injections in the past 6 months or had previously had surgery to the calf musculature. Six of the children wore an ankle foot orthosis (AFO) either unilaterally or bilaterally during the day prior to the casting period and all had worn orthoses in the past.

2.1. Study design

We used a randomised crossover design. The participants in the study were allocated to one of two groups by randomisation, with a component of minimisation to help ensure balanced groups in terms of diagnosis (hemiplegia and diplegia), age and gender.

For each group, there was a control and casting period. Those in Group A received casts immediately and those in Group B received casts after a 3 month control period (see Fig. 1). Each child was assessed at 0, 5 and 12 weeks in both the control and casting phases. Twelve weeks was chosen as the study interval for a crossover trial based on the findings from the Corry et al. [13] study that ankle range returned to the baseline value at 12 weeks following casting.

2.2. Casting

Below knee casting was applied by the same paediatric physiotherapists for each child. While lying prone on a couch, the child had their ankle maintained in maximum passive dorsiflexion with their knee flexed to 90°. Stockinette was used to cover the limb, compressed orthopaedic felt was applied over the osseous prominences, and undercast padding (Soffban) was used to protect the limb. Fibreglass casting material (Scotchcast) was then applied. The foot was maintained in neutral hindfoot alignment by a second physiotherapist during the application of the cast and while the cast was setting. If a neutral dorsiflexed/plantarflexed position of the ankle was not achieved in the cast, a wedge of foam was posted either under the heel of the cast for a plantarflexed position or under the toes of the cast for a dorsiflexed position to facilitate a neutral knee position during walking. A plaster boot was provided to protect the cast and the participants were encouraged to stand and walk, and to continue to participate in their usual activities as able. Following each weekly change of cast, passive ankle dorsiflexion range was reassessed. Another cast was applied if ankle dorsiflexion range had increased and the target range had not yet been achieved. Casting was ceased if no further gain in range was achieved or if the target amount of dorsiflexion, typically 10°, was achieved.

2.3. Investigations

Each assessment involved a number of tests. Clinical measurements of maximum passive ankle dorsiflexion range with the knee held in both flexion and extension were taken using a hand held goniometer. The range was taken as the angle between the line along the fibula and the line made...
along the lateral side of the hindfoot. Three dimensional gait analysis (3DGA) (Vicon 612, 7 camera system; 3 AMTI force plates) was used to collect information about each participant’s independent barefoot walking at a self-selected speed. Selected variables from the mean sagittal plane motion at the joints of the lower limb during stance and swing, as well as spatio-temporal parameters, were extracted from 5 selected walking trials for each visit. The Normalcy Index (NI) for walking was calculated from each of the five selected trials according to Schutte et al. [28]. The greater the value of this index, the more the gait pattern is removed from that seen in the typically developing population. The mean value was used in statistical analysis. Parents of the subjects were asked to complete the Gillette Functional Assessment Questionnaire [29] at each assessment and were asked to report the maximum walking distance the child could achieve.

The change in mean value over the first 5 weeks and over the 12 weeks in both the control period and casting period was calculated for each separate parameter. A paired t-test was used to compare the mean value of the changes in the two phases.

3. Results

The children in the group ranged in age from 6 years 1 month to 10 years 3 months (mean age: 7 years 1 month) and there were four males and five females. The mean GMFCS was 1.55 (range 1–3) and the mean Gillette FAQ 8.55 (range 7–10) for the group. One child used a posterior walking aid, while eight walked independently. There was minimal difference seen between the two groups for any of the parameters listed in Table 1. Eight children had two changes of cast and one child had three changes of cast. Seven children had casts on the most affected limb only and two children were cast bilaterally (a total of 11 limbs). Following casting, six children were issued with an AFO to be worn on the cast limb during the day. Two children who wore AFOs prior to casting were not reissued with them following casting and one child who did not wear an AFO prior to casting was issued with one following casting.

Since this was a crossover trial, data from individual subjects were compared in the treatment and control phases. Therefore, the changes in parameters during each assessment interval (0–5 weeks and 0–12 weeks) in the casting phase are compared to the same intervals in the control phase. The results are detailed in Table 2.

Relative to the control period, there was a significant increase in passive dorsiflexion range measured with the knee in extension at 5 weeks. However at 12 weeks, no significant change was found from baseline. Some improvements in passive dorsiflexion range measured with the knee in flexion was achieved at 5 weeks and maintained at 12 weeks.

Cadence, speed and stride length were not significantly changed by casting, though the period of single support was reduced by casting at the 5 week assessment. The percentage of time spent in single support was not significantly different at 12 weeks.

Ankle dorsiflexion in single support and swing increased significantly at 5 weeks but by 12 weeks significant differences could not be detected. Overall, knee flexion increased in single support at both 5 weeks and 12 weeks but not to significant levels. Additionally, minimum hip flexion in single support significantly increased at 5 weeks but was close to the baseline measurement at 12 weeks.

The mean NI calculated on the cast limb was significantly greater than that calculated for the non-cast limb in each case, both prior to and following casting (p = 0.02 and 0.04). The mean change in the NI over the 5 and 12 week periods of the casting and control phases was not significantly different.

Table 2

<table>
<thead>
<tr>
<th></th>
<th>0–5 Week</th>
<th>Control</th>
<th>p</th>
<th>0–12 Week</th>
<th>Casting</th>
<th>Control</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Clinical Examination</strong></td>
<td></td>
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<tr>
<td>Passive DF (°) (knee flexed)</td>
<td>7.55 (2.54)</td>
<td>-2.45 (2.9)</td>
<td>&lt;0.01*</td>
<td>5.3 (4.5)</td>
<td>-1.55 (2.1)</td>
<td>0.08</td>
<td></td>
</tr>
<tr>
<td>Passive DF (°) (knee extended)</td>
<td>3.46 (7)</td>
<td>-2.55 (3.4)</td>
<td>0.02*</td>
<td>1 (2.8)</td>
<td>-2.45 (5.4)</td>
<td>0.45</td>
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<tr>
<td><strong>Spatio-temporal parameters</strong></td>
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<tr>
<td>Speed (m/s)</td>
<td>0.04 (0.2)</td>
<td>0.05 (0.2)</td>
<td>0.90</td>
<td>-0.01 (0.1)</td>
<td>0.02 (0.2)</td>
<td>0.63</td>
<td></td>
</tr>
<tr>
<td>Cadence (step/min)</td>
<td>3.89 (10.3)</td>
<td>8.7 (17.6)</td>
<td>0.49</td>
<td>-5.33 (7)</td>
<td>2.9 (14.6)</td>
<td>0.17</td>
<td></td>
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<tr>
<td>Stride length (m)</td>
<td>0.012 (0.1)</td>
<td>-0.11 (0.3)</td>
<td>0.28</td>
<td>0.04 (0.07)</td>
<td>-0.01 (0.1)</td>
<td>0.27</td>
<td></td>
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<tr>
<td>Time in single support (%)</td>
<td>-1.19 (1.2)</td>
<td>0.75 (2.5)</td>
<td>0.05*</td>
<td>-1.55 (2.1)</td>
<td>0.77 (2.8)</td>
<td>0.08</td>
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<td><strong>Kinematics</strong></td>
<td></td>
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<tr>
<td>Max ankle DF (°) Single Support</td>
<td>2.69 (6.19)</td>
<td>-3.3 (4.3)</td>
<td>0.01*</td>
<td>0.2 (4.8)</td>
<td>0.27 (5.3)</td>
<td>0.99</td>
<td></td>
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<tr>
<td>Max ankle DF (°) Swing</td>
<td>3.44 (5.09)</td>
<td>-3.41 (4.1)</td>
<td>0.01*</td>
<td>1.067 (4.8)</td>
<td>-0.77 (4.2)</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>Minimum knee flexion (°) Stance</td>
<td>2.38 (6.36)</td>
<td>-2.75 (5.9)</td>
<td>0.07</td>
<td>3.79 (4.1)</td>
<td>-1.43 (8)</td>
<td>0.14</td>
<td></td>
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<tr>
<td>Minimum hip flexion (°) Stance</td>
<td>1.6 (3.34)</td>
<td>-2.58 (4.4)</td>
<td>0.04*</td>
<td>2.81 (4.1)</td>
<td>1.04 (5.2)</td>
<td>0.64</td>
<td></td>
</tr>
<tr>
<td>Normalcy Index</td>
<td>-81.1 (178)</td>
<td>25.36 (181)</td>
<td>0.29</td>
<td>7.55 (60)</td>
<td>13.5 (167)</td>
<td>0.97</td>
<td></td>
</tr>
</tbody>
</table>

*p-Values are given for significant differences between control and treatment phases.

\(p < 0.05\).
Six subjects remained at the same level on the Gillette FAQ, 2 subjects reduced a level and 1 subject gained a level on the Gillette FAQ following casting. Only one subject’s parents reported a gain in significant change maximum walking distance (from 2 to 5 miles). The subject who relied on the Kaye walker for assistance was able to take a greater number of steps independently 12 weeks following casting and this was maintained at 24 weeks following casting.

4. Discussion

We identified small but significant changes in passive and dynamic dorsiflexion range at the ankle due to serial casting at 5 weeks following the first cast application. However, the only significant result at the 12 week assessment was a small improvement in passive ankle dorsiflexion measured with the knee in flexion. No changes were noted in the functional measures used in this study (Gillette Functional Assessment Questionnaire, maximum walking distance and Normalcy Index).)

The changes we found due to casting were of similar magnitude and longevity to those reported by Corry et al. [13] and a little less than those reported by Brouwer et al. [20] and Glanzman et al. [24]. In contrast, Kay et al. [23] and Ackman et al. [15] found much greater and longer lasting changes. These workers used much longer periods of immobilisation and routinely used night splinting and AFOs after cessation of casting.

It is possible to interpret the disparity between our results and those of Kay et al. and Ackman et al. by reference to the literature that explores the structural response of young animals to stretch casting (see the works of Tardieu and Crawford as described in Gossman et al. [30]). These authors found that when muscles in young animals were stretched for short periods (days), sarcomerogenesis occurred within the muscle belly, whereas if the immobilisation period was prolonged, the tendon became elongated and sarcomere subtraction occurred. This was in contrast to results from adult animals where sarcomerogenesis seems to be the primary adaptation to short term and prolonged immobilisation in a lengthened position. By extrapolation, tendon adaptation in children with SCP may occur secondary to prolonged immobilisation, while adaptation within the muscle belly could be secondary to short-term stretch immobilisation. The mechanisms of stretch adaptation could be investigated using ultrasonic imaging as described by Shortland et al. [31] and Fry et al. [32].

There are possible iatrogenic consequences to differential elongation of belly and tendon. The ratio of belly to tendon length is believed to be an important biomechanical parameter, controlling the active range and elasticity of the musculo-tendinous unit [33]. Also, in long-term immobilisation muscle atrophy may occur secondary to a loss of tension in the musculo-tendinous unit. Experiments using servomotor equipment similar to those conducted by Brouwer [25] and Lin et al. [26] could explain the force length properties of the musculo-tendinous complex before and after prolonged immobilisation. However, in terms of the outcome measures reported, the results of prolonged immobilisation are more impressive than those from short-term stretch casting.

4.1. Limitations

We chose a crossover design to improve the power of our statistics and to accommodate a clinical imperative to cast. The length of the casting and control intervals were informed by the study by Corry et al. [13] in which passive and dynamic ranges had returned to baseline values at 12 weeks. However, in crossover designs there is potential for the effects of treatment to carry over into the control phase for the children who were cast immediately (Group A). To assess this, we compared the mean changes in the selected parameters for the control period in Groups A and B. The changes were similar, suggesting that carry-over is not a cause for concern, though our sample size is small (six limbs in Group A and five limbs in Group B).

4.2. Clinical implications

The method of serial casting adopted at our centre is one of the least aggressive reported in the literature, resulting in some of the mildest changes. It is possible that in the short-term serial casting delays the progression of deformity in some children, but our results indicate that casts would need to be applied every 12 weeks to maintain range. This represents a significant inconvenience to the child and their family. The alternatives are to cast for longer periods or to not cast at all. Surgical intervention results in similar changes in range, 1 year after treatment, to long-term immobilisation [34,35]. It is possible that these two interventions have similar effects on the musculo-tendinous structures. Any deleterious effects of prolonged immobilisation may only become evident with time, as the ankle plantarflexors of these children are required to support a dramatic increase in body weight as they grow. SCP is a heterogenous condition and although the mean change in the group after serial casting is small, there is substantial variation in the response of children with SCP to this and other interventions. If clinicians were to know the specific structural impairments of each patient, treatment selection could be refined for the individual.

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References


