



# PASSIVE STRETCHING AND ITS EFFECT ON SPASTICITY AND RANGE OF MOTION IN CHILDREN WITH CEREBRAL PALSY

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## ABSTRACT

**Study Design:** Only research studies published in peer-reviewed journals in the last two decades and published in the English language were included. Studies centered on surgical or pharmacological interventions were not included. To examine the strengths and weaknesses of these studies, the Physiotherapy Evidence Database (PEDro) scale and Sackett's levels of evidence were used. **Objectives:** The aim of this paper is to analyze literature published in the past two decades, which explores the effects of stretching when used to reduce spasticity and increase range of motion in children with spastic cerebral palsy (CP), as well as to address the effects of manual versus positional stretching as provided by physical therapists. **Background:** Physical therapists believe we can decrease joint degradation due to abnormal posture, as well as increase mobility and independence with a focus on the reduction of spasticity during posture and gait. A consensus in current literature seems to be that passive stretching is used widely to reduce spasticity in children with CP, but without scientific evidence to provide a justification for its use or to dictate the conditions in which to administer this treatment. **Methods and Measures:** The literature search for stretching in children with CP was conducted using the following key words: *stretching, positioning, serial casting, spasticity, range of motion, cerebral palsy, and children*. The following databases were used: Academic Search Complete, CINAHL, Cochrane Library, PEDro, Pubmed, ScienceDirect, SCOPUS, and SPORTDiscus. **Results:** A total of 13 articles on stretching in children with cerebral palsy were found from the years 1990 to 2011. Two individual studies were found in which manual stretching was the intervention. Nine individual studies were found in which positional stretching was the intervention, four of which serial casting was the intervention. Two systematic reviews exist in the last two decades that explore the effect of stretching in children with CP, however, neither encompass all of the studies reviewed in this paper nor do they discuss serial casting as a form of positional stretching. **Conclusion:** Taken together, the individual studies using positional stretching and the small randomized controlled trial using electrical stimulation in addition to manual stretching led to better outcomes for reducing spasticity and increasing passive range of motion compared to manual stretching alone.

research report is a systematic review of literature pertaining to the effectiveness of interactive gaming versus traditional rehabilitation methods in balance training post cerebral vascular attack (CVA).

## Background

In the United States, researchers have shown there has been an increase in the prevalence of cerebral palsy (CP) from 1.7 to 2.0 per 1000 one-year survivors.<sup>19</sup> The results from the United States are similar to the statistics from Europe, showing the prevalence of CP as 2.49 per 1000 live births in Sweden, thereby making CP a diagnosis commonly seen by pediatric physical therapists.<sup>5</sup> The latest consensus definition of cerebral palsy is a “group of permanent disorders of the development of movement and posture, causing activity limitation, that are attributed to non-progressive disturbances that occurred in the developing fetal or infant brain.”<sup>15</sup> When classified by the dominant type of tone or movement abnormality, 72 to 91 percent of children diagnosed with cerebral palsy have spasticity as their predominant neuromotor abnormality.<sup>11</sup> Spasticity is expressed as a velocity-dependent increase in muscle tone, hyper-reflexia, and the presence of primitive reflexes.<sup>1,7</sup> Any degree of spasticity affecting the lower extremities can cause abnormal posture, delayed motor development, and atypical gait patterns.<sup>1</sup> The presence of spasticity contributes to secondary musculoskeletal problems, such as muscle/tendon contractures, bony torsion, hip displacement, and spinal deformity as expanded on in the latest consensus definition of cerebral palsy.<sup>15</sup> Physical therapists believe we can decrease joint degradation due to abnormal posture, as well as increase mobility and independence with a focus on the reduction of spasticity during posture and gait.

The aim of this paper is to analyze current literature, which explores the effects of stretching when used to reduce spasticity and increase passive range of motion (PROM) in children with spastic cerebral palsy. A consensus in current literature seems to be that passive stretching is used widely for this population, but without scientific evidence to provide a justification for its use or to dictate the conditions (frequency, duration) in which to administer this treatment.<sup>13</sup> The purpose of this paper is to review the literature published in the past two decades, as well as to address the effects of manual versus positional stretching.

Manual stretching is herein defined as a passive stretch provided by a physical therapist and held for 30 to 60 seconds. In comparison, positional stretching is accomplished by placing the child in a position for longer periods of time, greater than 15 minutes. The desired position can be supported by hand, or may require the use of a tilt table to maintain the position under the guidance of a physical therapist. Serial casting, without the adjunct of botulinum toxin, can be used as an additional means to provide a sustained stretch, which can be applied and monitored by physical therapists.

Pharmacological interventions such as Baclofen and botulinum toxin should be mentioned as tools to decrease spasticity; however this literature review focuses on the benefits of manual and positional stretching as provided by physical therapists. The functional outcomes of pharmacological interventions are monitored by physical therapists, however they are aspects ultimately provided by other members of the health care team involved in a child’s care. Studies that incorporate modalities, such as electrical stimulation, will be included in the review as physical therapists are trained to use electrical stimulation in a clinical setting.

## Methods

The literature search for stretching in children with CP was conducted using the following key words: *stretching, positioning, serial casting, spasticity, range of motion, cerebral palsy, and children*. The search was conducted most recently in September of 2011 in the following databases: Academic Search Complete, CINAHL, Cochrane Library, PEDro, Pubmed, ScienceDirect, SCOPUS, and SPORTDiscus. Only research studies published in peer-reviewed journals in the last two decades and published in the English language were included (Table 1). Studies

centered on surgical or pharmacological interventions were not included, as this literature review focuses on the benefits of manual and positional stretching as provided by physical therapists.

**TABLE 1:** Description of Searches Conducted on Stretching in Children with Spastic CP

Databases	Pubmed	CINAHL	Science Direct	Cochrane Library	SPORT Discus	Academic Search Complete	SCOPUS	PEDro
Date of Search	September 6, 2011	September 6, 2011	September 6, 2011	September 6, 2011	September 6, 2011	September 6, 2011	September 6, 2011	September 6, 2011
Total no. articles found	195	168	12	16	14	48	197	9
No. articles appropriate for review	12	7	2	3	2	3	11	5
Akbayrak et al <sup>1</sup> (2005)	x	x				x		
Brouwer et al <sup>2</sup> (1998)	x	x					x	
Cottalorda et al <sup>3</sup> (2000)	x	x						
Fragala et al <sup>4</sup> (2003)		x					x	
Jain et al <sup>6</sup> (2008)	x	x		x			x	x
Khalili et al <sup>7</sup> (2008)	x				x		x	
Lespargot et al <sup>8</sup> (1994)	x						x	
McNee et al <sup>10</sup> (2007)	x	x			x	x	x	x
O'Dwyer et al <sup>12</sup> (1994)	x						x	
Pin et al <sup>13</sup> (2006)	x	x	x			x	x	x
Richards et al <sup>14</sup> (1991)	x	x					x	x
Tremblay et al <sup>17</sup> (1990)	x	x					x	x
Wiat et al <sup>18</sup> (2008)	x						x	

**TABLE 2:** Levels of Evidence for Studies Evaluating Stretching in Children with Spastic CP

Study	PEDro Scale <sup>9</sup>	Sackett Level of Evidence <sup>16</sup>	Type of Study
Akbayrak et al <sup>1</sup> (2005)	4/10	3B	Case controlled study
Brouwer et al <sup>2</sup> (1998)	5/10	2B	Cohort study/Low quality randomized controlled trial
Cottalorda et al <sup>3</sup> (2000)	4/10	2C	Outcomes Research
Fragala et al <sup>4</sup> (2003)	4/10	3B	Case controlled study
Jain et al <sup>6</sup> (2008)	5/10	3B	Case controlled study
Khalili et al <sup>7</sup> (2008)	6/10	2B	Cohort study/Low quality randomized controlled trial
Lespargot et al <sup>8</sup> (1994)	3/10	3B	Case controlled study
McNee et al <sup>10</sup> (2007)	7/10	2B	Cohort study/Low quality randomized controlled trial
O'Dwyer et al <sup>12</sup> (1994)	8/10	2B	Cohort study/Low quality randomized controlled trial
Pin et al <sup>15</sup> (2006)	N/A	3A	Systematic Review
Richards et al <sup>14</sup> (1991)	6/10	2B	Cohort study/Low quality randomized controlled trial
Tremblay et al <sup>17</sup> (1990)	6/10	2B	Cohort study/Low quality randomized controlled trial
Wiart et al <sup>18</sup> (2008)	N/A	3A	Systematic Review

**TABLE 3:** Description and Outcomes of Studies Evaluating Stretching in Children with Spastic CP

Study	Participants	Intervention	Positional or Manual	Important Outcome Measures	Important Results
Akbayrak et al <sup>1</sup> (2005)	11 males, 5 females with spastic diplegia (age 4-11 yr) MAS* score of 3 at the gastro-soleus muscle GMFCS <sup>1</sup> level not specified	Placed in position of hips abducted 45 and externally rotated, knees extended, ankles in neutral for 20 minutes supported by physiotherapist	Positional	H reflex*, H/M ratio*, MAS , Goniometry: ankle dorsiflexion	Mean decrease in H reflexes* of 5.17 mV (SD 3.61), H/M ratios* of 0.51 mV/mV (SD 0.20), and MAS* values of 0.38 points; Mean increase in goniometric measurements of 9.25°
Brouwer et al <sup>2</sup> (1998)	6 males and 4 females with spastic hemiplegia (4), spastic diplegia (6) (age 4-14 yr) 10 age-matched control participants GMFCS <sup>1</sup> level not specified	Below knee casts applied weekly over a 3 week period; assessed pre-casting, post-casting (within 3 days of removal), follow up (6 weeks after removal)	Positional (Serial Casting)	Goniometry: ankle dorsiflexion Reflex excitability	Significant increase in dorsiflexion from baseline to post-casting (p<0.01), and to a lesser extent from baseline to follow up (p<0.05); Decrease in resistance to passive stretch (p<0.002)
Cottalorda et al <sup>3</sup>	11 males and 9 females with spastic	3 successive below knee casts applied over a period of 3	Positional	Goniometry: ankle dorsiflexion with knee	After cast removal the mean dorsiflexion was 20° (knee extension) and 28° (knee flexion); at the

(2000)	hemiplegia (10) and spastic diplegia (10) (age 2-5 yr) GMFCS <sup>†</sup> level not specified	weeks; night splint and physical therapy after cast removal; assessed after treatment at 1 month, 6 months, 1 year, then every 6 months for an average of 3 years	(Serial Casting)	flexed and extended	latest follow up the mean dorsiflexion as 9° (knee extension) and 18° (knee flexion)
Fragala et al <sup>4</sup> (2003)	4 males, 3 females with spastic quadriplegia (6), myelodysplasia T10 (1) (age 4-18 yr) GMFCS <sup>†</sup> level V	Passive stretch of hip flexors, hip extensors, hip adductors, knee flexors, and knee extensors, held for 40-60 seconds, repeated 3 times, 1-2 times per week	Manual	Goniometry: hip flexion, hip extension, hip abduction, knee flexion, knee extension	No consistent changes in PROM across participants
Jain et al <sup>6</sup> (2008)	22 children with spastic diplegia (15), spastic paraplegia (5), spastic tetraplegia (2) (age 3-12 yr) MAS* score of 2 or 3 at the targeted muscle(s) GMFCS <sup>†</sup> level not specified	Casts applied weekly over a 4 week period, as follows: groin to toe (20 limbs), cylindrical (1 limb), short leg (1 limb), short leg without abductor bar (11 limbs), short leg with abductor bar (11 limbs)	Positional (Serial Casting)	Goniometry: hip, knee, ankle MAS*: knee and ankle	Significant improvement in Thomas test (p<0.001), hip abduction (p<0.001), popliteal angle (p<0.001), and ankle dorsiflexion with knee flexion and extension (p<0.001); All values were significant at follow up except ankle dorsiflexion; 100% of participants showed improvement in MAS at knee and 90.91% at ankle
Khalili et al <sup>7</sup> (2008)	5 males, 6 females with cerebral palsy (age 11.6-14.0 yr) GMFCS <sup>†</sup> level not specified	One leg received manual stretching of hamstrings for 3 sets of 30 seconds, 5 days per week; the other leg received manual stretching of the hamstrings with the addition of electrical stimulation to the quadriceps for 30 minutes, 3 times per week	Manual	MAS, Goniometry: knee extension	The addition of electrical stimulation showed a significant decrease on MAS* of 0.8 points (05% CI 0.1 to 1.5, p = 0.046) and significant increase in passive knee extension of 4 degrees (95% CI 0 to 7, p=0.04)
Lespargo et al <sup>8</sup>	3 males, 7 females with spastic	Passive stretch of hip adductors for 15-20 minutes,	Positional	Passive stretch distance (PSD), angle of first	Trend towards prevention of muscle contracture with stretching and regular seat use, as

(1994)	quadriplegia (4), spastic diplegia (5), spastic hemiplegia (1) (age 9-13 yr) GMFCS <sup>†</sup> level not specified	5 to 7 hours per day spent in a seat which moderately extended the adductors		perceptible tension ( $A_0$ ), angle showing tension in the muscle belly when movement is stopped ( $A_{max}$ ).	demonstrated by no significant change in PSD during the intervention period
McNee et al <sup>10</sup> (2006)	4 males and 5 females with spastic hemiplegia (3), spastic diplegia (6) (age 6-10 yr) mean GMFCS <sup>†</sup> level 1.55 (range 1-3)	Below knee casts applied for a 12 week casting period and removed for 3 month control period and, assessed at 0, 5, and 12 weeks; One group received casts immediately, one group received casts after control period	Positional (Serial Casting)	Goniometry: ankle dorsiflexion with knee flexed and extended, 3D gait analysis, Gillette Functional Assessment Questionnaire	Significant increase in passive dorsiflexion measure with knee extension at 5 weeks, no significant change at 12 weeks; no significant change in stride, speed, and cadence; 6 participants remained at the same level on the Gillette, 2 reduced a level, 1 gained a level

O'Dwyer et al <sup>12</sup> (1994)	15 participants (gender not specified) with spastic cerebral palsy (age 6-19 yr) GMFCS <sup>†</sup> level not specified	Passive stretch of triceps surae for a 30 min session, 3 times per week, for 5 months with video feedback of the EMG response of the triceps surae	Positional	Spasticity: tonic stretch reflex	Significant reduction of spasticity by at least 50% on average
Pin et al <sup>13</sup> (2006)	N/A	N/A	Both	N/A	N/A
Richards et al <sup>14</sup> (1991)	7 males, 12 females with spastic diplegia (12), spastic hemiplegia (7) (age 3-13 yr) GMFCS <sup>†</sup> level not specified	Stood in modified tilt table for 30 min with ankle in maximal DF via adjustable footplate	Positional	Muscle activation during gait of triceps surae & tibialis anterior	No significant changes in triceps surae activation during gait ( $p>0.05$ ), only significant change was a decrease in tibialis anterior activation during 0-16% of the gait cycle
Tremblay et al <sup>17</sup> (1990)	22 participants (gender not specified) with spastic diplegia (13), quadriplegia (2), hemiplegia (7) (age 3-14 yr)	Stood in modified tilt table for 30 min with ankles dorsiflexed	Positional	Torque and EMG activity of triceps surae & tibialis anterior during passive movements and maximal static voluntary contraction	Significant decreased response to passive movement lasting up to 35 minutes after the stretch measured by EMG activity [ $1.67 \mu V \cdot s$ (SD 0.59)], increased capacity to activate the plantar flexors with mean increase in torque of $+2.57 \text{ Nm}$ (SD 3.51)

	GMFCS' level not specified				
Wiant et al <sup>18</sup> (2008)	N/A	N/A	Both	N/A	N/A

To examine the strengths and weaknesses of these studies, the Physiotherapy Evidence Database (PEDro) scale<sup>9</sup> was used, as well as Sackett's levels of evidence<sup>16</sup> (Table 2). The PEDro scale was developed to determine the quality of randomized controlled trials specific for rehabilitation based on 11 criteria.<sup>9</sup> Each criterion is worth one point, and a score is given out of a possible of 10 points, as the first criterion "eligibility criteria were specified" is a measure of external validity whereas as other criteria are measures of internal validity. A range in scores from 3/10 to 8/10 were found, with a mode of 4/10 and 6/10 (Table 2).

Sackett's levels of evidence<sup>16</sup> were used in conjunction with the PEDro scale to further describe the level of evidence for studies that are not randomized controlled trials. Several of the studies in this review have been classified as 2B, "cohort study/low quality randomized controlled trial," according to Sackett's levels of evidence because they have one or more major, or three or more minor methodological flaws (Table 2).<sup>16</sup> Examples of methodological flaws include small sample sizes, lack of a control group, and lack of blinded subjects and testers.

## Results

A total of 13 articles on stretching in children with cerebral palsy were found from the years 1990 to 2011 (Table 3). Two studies were found in which manual stretching was the intervention.<sup>4,7</sup> Nine studies were found in which positional stretching was the intervention,<sup>1,8,12,14,17</sup> with four addressing serial casting specifically.<sup>2,3,6,10</sup> Two systematic reviews exist in the last two decades which explore the effect of stretching in children with spastic CP, however, neither encompass all of the studies reviewed in this paper, and neither address serial casting as a means of providing a positional stretch.<sup>13</sup> **Manual Stretching (duration: 30-60 seconds)**

As stated previously, of the 13 articles reviewed, two individual studies with small sample sizes were found which investigated the effectiveness of manual stretching on increasing passive range of motion and decreasing spasticity in children with cerebral palsy.<sup>4,7</sup> A small, randomized within-participant controlled trial<sup>7</sup> investigated the use of reciprocal inhibition of the stretched muscle in 11 adolescents with spastic diplegic CP ages 11 to 14 years. One leg of each child received only manual hamstring stretching for three sets of 30 seconds, while the other leg received the experimental treatment (Table 3). The experimental legs received electrical stimulation applied to the quadriceps for 30 minutes three times a week with the following parameters: frequency of 30 Hz, pulse width 0.4 ms, duty cycle four seconds on four seconds off, ramp up of 0.5 s, and an intensity set as high as the participant would tolerate to obtain a visible contraction. After the stimulation, three 30-second stretches were applied to the hamstrings provided by a physical therapist.

The outcome measures used to quantify spasticity and contracture were the modified Ashworth Scale (MAS) and maximum passive knee extension using goniometry, respectively. In legs that received electrical stimulation in addition to passive stretching, a mean decrease on the MAS of 2.0 points (SD 0.9) was found, whereas a mean decrease of 1.2 points (SD 0.6) was found for the control group. The mean difference in decrease with the addition of electrical stimulation was 0.8 points (95% CI 0.1 to 1.5,  $p = 0.046$ ). For passive knee extension, the mean increase for the experimental group was 13 degrees (SD 5) and nine degrees (SD 3) for the control group. The mean difference in increase in passive knee extension with the addition of electrical stimulation was four degrees (95% CI 0 to 7,  $p = 0.04$ ).<sup>7</sup>

A pilot study Fragala et al<sup>4</sup> examined changes in passive range of motion of the hip flexors, hip adductors, knee flexors, and knee extensors after manual stretching. Seven students age four to 18 years received three repetitions of lower extremity passive stretching, held for 40 to 60 seconds, and administered up to two times per week while school was in session (Table 3). Passive range of motion was measured before and after naturally occurring periods of school vacation, in which the students did not receive physical therapy services.

Six joint motions were measured bilaterally for six of the seven participants by goniometry. Popliteal angle was not measured for one child because she had less than 90 degrees of hip flexion. The total of 82 motions included: hip flexion, hip extension, hip abduction, popliteal angle, knee extension, and knee flexion. A change of greater than eight degrees was deemed as a change not due to measurement error and data was reported as the number of joints for each child that either increased or decreased by greater than or equal to eight degrees. The only significant pattern of change across all subjects was found following the first non-intervention phase, with a decrease in PROM in 28 of the 82 measured motions ( $p=0.046$ ). Otherwise, in general for all of the seven students, neither a consistent pattern of gaining passive range of motion after intervention, nor a loss of motion after naturally occurring periods without intervention were found. The authors did report that during each of the phases, PROM was maintained in at least one half of the joint motions monitored.<sup>4</sup>

### **Positional Stretching (duration: greater than 15 minutes)**

Of the 13 articles reviewed, nine individual studies were found which met the parameters for positional stretching, including a stretch which lasted for greater than 15 minutes with bodily support from a physical therapist,<sup>1,8</sup> a tilt table,<sup>12,14,17</sup> or serial casting.<sup>2,3,6,10</sup> Three of the nine individual studies investigated a single session of positional stretching and were not followed up with further data collection.<sup>1,14,17</sup> Statistically significant decreases in spasticity were found after a single session, however a single session of positional stretching did not significantly alter triceps surae activation during gait.<sup>14</sup>

In a case controlled study<sup>1</sup> 16 children diagnosed with spastic diplegia ages four to 11 years were placed in a sitting position with hips abducted nearly 45 degrees and externally rotated, knees extended, and ankles place in a neutral position for 20 minutes (Table 3). When measured before and after the 20 minute positioning, a statistically significant decrease in Hoffman

(H) response, Hoffman reflex/motor response (H/M) ratio, and MAS value were found, in addition to an increase in passive ankle range of motion ( $p<0.05$ ). The mean decrease in H response was 2.29 mV and decrease in H/M ratio was 0.23 mV/mV. A mean decrease of 0.38 points was found for the MAS. The mean increase in passive dorsiflexion was 9.25 degrees.

Tremblay et al<sup>17</sup> conducted a cohort study/low quality randomized controlled trial with 22 children diagnosed with cerebral palsy ages three to 14 years. Controls were matched for type of cerebral palsy and were compared to the experimental group who stood at a modified tilt table with the ankles in dorsiflexion for 30 minutes (Table 3). A statistically significant decrease in spasticity of the plantar flexors, as measured by torque and EMG activity during passive movement, was shown to last up to 35 minutes after the stretch ( $p<0.05$ ). The mean increase in torque of the plantar flexors after the positional stretch was +2.57 Nm (SD 3.51) for the intervention group and was +0.40 Nm (SD 2.13) for the control group. The increase in torque of the plantar flexors is significantly related to the increased ability to activate the triceps surae compared to the control group. The average EMG activity during passive movement for the experimental group was 1.67  $\mu\text{V}\cdot\text{s}$  (SD 0.59) compared to 0.96  $\mu\text{V}\cdot\text{s}$  (SD 0.25) for the control group.

In a study by Richards et al<sup>14</sup> the effect of a single session of positional stretch of the plantar flexors for 19 children ages three to 13 years with spastic CP after 30 minutes on a tilt table did not show significant changes in the activation of the triceps surae during gait as compared to the control group who was seated and played for 30 minutes ( $p>0.05$ ). The only significant difference in muscle activation was the EMG post/pre ratio for the tibialis anterior indicating a decrease in activity during the first 0-16 percent of the gait cycle (Table 3). The ratio was 0.79 for the experimental group and 1.04 for the control group. Changes in spatiotemporal gait parameters were found, such as mean change in stride length of two centimeters for both groups, and change in cadence of 10 steps/min for the experimental group and six steps/min for control group, however none of the gait parameters were statistically significant.

Two individual studies that evaluated positional stretch followed a typical school-age program schedule, in which passive stretching was performed up to three sessions per week for several weeks at a time.<sup>8,12</sup> Lespargot et al<sup>8</sup> conducted a case controlled study of 10 adolescents with CP ages 9 to 13 years who received positional stretching of the hip adductors for up to three one-hour treatment sessions a week, in which 15 to 20 minutes were spent on passive stretching (Table 3). The remainder of the treatment time included participating in exercises to strengthen the abductor muscles such as crawling and standing on one foot. The participants were also given a special chair that moderately stretched the hip adductors to use in class, during meals, and on the weekends for a total of five to seven hours per day.

Outcome measures included passive stretch distance (PSD), which was used to determine if a contracture was present in the hip adductors, measured with the knee flexed and extended. PSD is the difference between the angle that tension is first perceptible with a passive stretch ( $A_0$ ) and the angle that movement is stopped ( $A_{max}$ ).<sup>8</sup> Measurements were taken on a control group of 20 typically developing children, as well as the 10 children with CP who had been receiving therapy regularly for at least one year. Participants who received passive stretching and the use of the special seat for five to seven hours a day showed no signs of contracture of the muscle body during periods of intervention as measured by no significant change in PSD. After a six to eight week holiday, four of the 10 children was given a tracking task, with responses on the screen from ankle contraction, however the ankle joint was against a fixed plate, unlike the experimental group.

A reduction of spasticity as measured by feedback of the stretch reflex, was significant only in the group that received the positional stretching.<sup>12</sup> The participants who received the stretching learned to reduce the sensitivity of their tonic stretch reflex by 50 percent on average. No changes were found in the degree of muscle contracture in any subject as measured by torque-angle characteristics.

Of the nine studies which met the criteria for positional stretching, four addressed the role of serial casting with the goal of inhibiting the over activity and reflex excitability of the ankle plantar flexors as well as providing increases in ankle dorsiflexion.<sup>2,3,6,10</sup> One of the studies had a control group of able-bodied children matched for age<sup>2</sup>, one study had randomized crossover design with a with CP were assessed and reductions in PSD were found ranging from a difference of 2.5 degrees to 16.0 degrees with knee bent. With knee extended measurements were not available for one child, and a decrease was found for 2 children ranging from 3.5 to 4.0 degrees, and an increase in 3.0 degrees for one child. Therefore, as evidenced by a decrease in PSD, contracture was present in all but one case after six to eight weeks without positional stretching and use of the adductor seat.

A randomized controlled trial<sup>12</sup> lasting five months found a statistically significant reduction of spasticity, as measured by sensitivity of the tonic stretch reflex, in eight participants with CP ages six to 19 years who received passive positional stretching of the triceps surae for three 30 minute sessions each week with video feedback of the EMG response of the triceps surae (Table 3). The control group who consisted of seven participants matched for type of CP

control and casting period for two groups<sup>10</sup>, and the other two studies had no controls.<sup>3,6</sup> The style of cast ranged from below knee casting to groin-to-toe casting, with below knee casting being the most common method, because plantar flexor spasticity with toe walking was the most prevalent patient presentations. The duration of cast application ranged from three to 12 weeks. Outcome measures included goniometry, modified Ashworth Scale, EMG reflex excitability, 3D gait analysis, and the Gillette Functional Assessment Questionnaire (Table 3).

In a randomized crossover study,<sup>10</sup> in which nine children with CP ages six to 10 years received below knee casts either before or after a three month control period, significant increases in dorsiflexion were found after five weeks of serial casting but not after twelve weeks. Cottalorda et al<sup>3</sup> conducted a study of twenty children with CP ages two to five years who received three successive below knee casts applied over a three week period (Table 3). After cast removal, mean dorsiflexion was shown to be 20 degrees and 28 degrees with knee extension and knee flexion, respectively.<sup>3</sup> After an average follow up of 3 years, average dorsiflexion in the same participants was shown to be 9 degrees and 18 degrees with knee extension and knee flexion, respectively.<sup>3</sup>

In a study by Brouwer et al,<sup>2</sup> ten children with spastic CP ages four to 14 years received below knee serial casts over a period of three weeks (Table 3). Ankle dorsiflexion and reflex excitability were assessed with goniometry and constant-tension springs attached to a footplate, respectively. Ten age-matched controls with no relevant medical history did not receive serial casting, but were used to contrast typical reflex excitability. For children with CP who received three weeks of below knee serial casting higher velocities were used post-casting ( $495.1 \pm 31.7^\circ/\text{s}$ ) than pre-casting ( $372.4 \pm 48.2^\circ/\text{s}$ ), evidence of a decrease in resistance to passive stretch ( $p < 0.002$ ). Along with a decrease in resistance to passive stretch a significant increase ( $p < 0.01$ ) in passive dorsiflexion range from baseline to post-casting was found, and to a lesser degree from baseline to six week follow up ( $p < 0.05$ ).

Jain et al<sup>6</sup> conducted a case controlled study with 22 children diagnosed with cerebral palsy ages three to 12 years who received serial casts over a four week period. Based on patient presentation appropriate casts included groin-to-toe, cylindrical, short leg, and short leg with abductor bar (Table 3). Significant improvements, represented as mean change for the right leg, were found after removal of serial casts in Thomas test ( $12.22 \pm 9.58$ ), popliteal angle ( $45.71 \pm 11.75$ ), dorsiflexion with knee extension ( $12.22 \pm 8.78$ ), and dorsiflexion with knee flexion ( $10.55 \pm 11.74$ ). All values were significant at follow up with the exception of ankle dorsiflexion with knee extension, with a mean change of  $4.50 \pm 9.26$  from baseline. Jain et al<sup>6</sup> also found a decrease in spasticity at the knee and ankle as measured by the MAS. Individual MAS grades were not provided, however the authors stated an improvement from an initial MAS grade of II or III at the knee in 100% and the ankle in 90.91%. Most of the children improved one to three grades, over a period of time, although less than 46% of participants maintained the improvements.<sup>6</sup>

## Discussion

With two studies conducted on manual stretching,<sup>4,7</sup> the body of research for this mode of stretching is limited. Both of these individual studies had similar parameters that included a 30 to 60 second stretch administered by a physical therapist and repeated three times with short breaks in between. The participants were of similar ages and had similar levels of disability.

These two studies using manual stretching had varying lengths of intervention periods, however, and the more frequent stretching program with additional electrical stimulation<sup>7</sup> yielded significant changes in range of motion and spasticity as measured by goniometry and the MAS (Table 3). One of the studies<sup>4</sup> implemented a standard program for school-age children with a frequency of one to two sessions per week over 31 weeks. This program accounted for periods of school vacation, lasting up to five weeks, in which the children did not receive the intervention. This study<sup>4</sup>, however, did not show consistent patterns of change in passive range of motion related to manual stretching. In contrast, Khalili et al<sup>7</sup> showed that an intense program of stretching five days a week with the addition of electrical stimulation to the antagonist three days a week, resulted in a mean increase of four degrees in passive knee extension with the addition of electrical stimulation and a mean decrease of 0.8 points on the MAS. Of the nine individual studies evaluating positional stretching, four<sup>1,8,12,17</sup> showed significant outcome results including decreases in EMG activity during passive motion,<sup>17</sup> decreases in stretch reflexes<sup>1,2,8</sup> and increases in goniometric measurements.<sup>1,2,3,10</sup> Of the nine individual studies with positive outcomes after positional stretching, two were single-session interventions (Table 3).<sup>1,17</sup> Single sessions, as well as weekly programs of positional stretching and serial casting, appear to have more of an effect on decreasing spasticity and increasing range of motion when compared to manual stretching alone.

As previously stated, most of the individual studies were structured as an intense weekly program of three to five days per week, or as single-session interventions. In a clinic setting school-age children are seen on a weekly or monthly basis, rarely five days per week or for just one session. Fragala et al<sup>4</sup> found no significant changes in passive range of motion when manual stretching was provided one to two days per week for up to 31 weeks, a schedule similar to a clinic setting with school-age children. However, a reduction of the tonic stretch reflex and decrease in occurrence of contracture has been shown with weekly positional stretching with the addition of video feedback of EMG response<sup>12</sup> as well as weekly positional stretching and the use of an adductor seat for five to seven hours per day.<sup>8</sup>

The addition of the adductor seat in the study by Lespargot et al<sup>8</sup> as well as knee and ankle exercises after serial casting by Jain et al<sup>6</sup>, are the only mentions of continuance of sustained stretching when the child is at home. Cottalorda et al<sup>3</sup> referenced regular physical therapy with repeated stretching after removal of serial casts, however they did not elaborate on stretching at home.

Future studies would benefit by addressing the role of the family in spasticity management by including a home exercise program for positional stretching. Physical therapists can train family members and provide them with individualized positions to obtain the desired stretch, as well as guidelines for duration and frequency based on the literature. The duration of positional stretching in the individual studies varies from 15 to 30 minutes, with studies using the tilt table lasting 30 minutes and studies using bodily support from a therapist lasting 15 to 20 minutes. In regards to serial casting, children are encouraged to walk and continue with usual activities as able after the initial 24 to 48 hours.<sup>3,6,10</sup>

As pointed out by Wiart et al<sup>18</sup> in a systematic review, according to the International Classification of Functioning, Disability and Health (ICF)<sup>20</sup> model, outcome measures such as passive range of motion should not be used to directly make assumptions about a change in activity level. For example, an increase in passive range of motion at the ankle addresses the level of “Body Structure and Function,” but it may not directly correlate with changes in riding a bike (activity) or partaking in recess activities (participation). The “Participation” level is unique in that the concept can be highly individual from patient to patient, and depends on how researchers choose to capture a change.

For example, if a child’s ankle motion is improved after a given intervention and he or she can walk with a more efficient gait pattern, but they prefer to sit and play video games after school, their “participation” has not changed. Although that particular intervention may not have been appropriate for that patient, because it did not match their goals or needs at that point in time, the intervention itself should not be discounted. Therefore, capturing changes at the “Participation” level is a complex domain.

The majority of the studies on stretching in children with cerebral palsy failed to include an outcome measure addressing the level of “Activity” or “Participation”<sup>1,4,7,8,12,17</sup> as defined in the World Health Organization ICF model.<sup>20</sup> Although studies have measured passive motion and spasticity, the available evidence does not support the use of manual stretching alone and is equivocal for positional stretching for children with spastic CP. The evidence is rather weak that changes are being made even at the “Body structure and Function” level.

The opportunity exists to explore multiple intervention studies and include measures at all levels of the ICF. For example, when a child has limited dorsiflexion that impedes his or her ability to stand with flat foot contact, interventions should address the “Body Structure and Function” level (e.g., casting, strengthening), “Activity” level (e.g., standing-reaching activities, balance activities), and “Participation” level. The key to the “Participation” level is identifying a task that is meaningful to the child and work toward that goal. The concept may be atypical for a research study, but multiple interventions aimed at a child’s movement goal that would be addressed by outcome measures at multiple levels of the ICF, represents the needs of the clinical community and will be a way to optimize clinical practice and maintain range of motion, but without scientific evidence to validate it’s use or define a protocol.

In the past two decades eleven individual studies were found which centered on the use of manual or positional stretching to reduce spasticity in children with CP. Two systematic reviews exist, however neither of them encompass all of the studies reviewed in this paper, and neither focus on serial casting. Although manual stretching is commonly used for children with spastic CP, the evidence does not support its use to improve passive range of motion and decrease spasticity. With the addition of electrical stimulation to the antagonist and an increased frequency of stretching interventions to three times per week, statistically significant increases in passive range of motion and decreases in spasticity have been found with manual stretching. More studies exist which examine positional stretching, and when looked at as a whole, statistically significant decreases in spasticity have been found after a single session of positional stretching. The evidence supports significant changes in passive range of motion as well as spasticity after three to 12 weeks of serial casting. A lack of studies exist which examine participation related to a child’s movement goals, as well as outcome measures at multiple levels of the ICF model.

## Conclusion

Cerebral palsy is a diagnosis commonly seen by pediatric physical therapists, and the compounded effects of spasticity of the lower extremities can be detrimental to a child's motor development. Physical therapists focus treatment on the reduction of spasticity to decrease joint degradation and maintain mobility in the growing child. According to current literature, a consensus seems to be that passive stretching is used widely with the intent to decrease spasticity

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