

Stretching with Children with Cerebral Palsy: What Do We Know and Where Are We Going?

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Purpose: To review research regarding mechanisms of muscle contracture in cerebral palsy (CP) and the effectiveness of stretching, and to discuss current physical therapy stretching practices. Community-based recreation opportunities that encourage flexibility and fitness are explored as alternatives to traditional therapy stretching approaches. **Summary of Key Points:** Mechanisms of muscle contracture in children with CP are unclear and clinical research evaluating the effects of stretching is inconclusive. Recent shifts in thinking about the management of children with CP suggest an increased emphasis on flexibility, fitness, and participation in activities that are meaningful to children and families. **Statement of Conclusions:** Additional research is needed to explore the structural changes that occur in the shortened muscles of children with CP and the effects of stretching practices used in pediatric physical therapy. **Recommendations for Clinical Practice:** Physical therapists can consider innovative alternatives that integrate flexibility and fitness goals with community-based recreation programs. (*Pediatr Phys Ther* 2008;20:173–178) **Key words:** active stretching, adolescent, cerebral palsy/complications, cerebral palsy/physiopathology, cerebral palsy/rehabilitation, child, exercise, human movement system, joint flexibility, passive stretching, muscle spasticity/etiology, muscle spasticity/rehabilitation, physical therapy modalities

INTRODUCTION

Muscle contractures contribute to loss of joint range of motion and decreased functional movement for children with a diagnosis of cerebral palsy (CP).^{1,2} Stretching programs are an important component of physical therapy intervention with this group of children. The use of muscle stretching is based on the assumptions that stretching will increase muscle extensibility, preserve joint range of motion for functional movement, and prevent or delay the need for orthopedic surgical interventions.^{3,4} Physical therapists use various strategies

for muscle stretching including: (1) passive stretching (the stretch is performed by another person and the child does not actively participate); (2) active stretching (the child initiates and/or maintains the stretch); or (3) prolonged positioning (positioning is used to achieve a longer duration stretch of a particular muscle or muscle group). All three techniques are often used in conjunction with other interventions such as splints and orthoses, serial casting, surgery, or spasticity reducing medications. Despite the widespread use of stretching as a physical therapy management strategy for children with CP, knowledge about the effectiveness of stretching techniques is limited for two reasons. First, the mechanisms and etiology of muscle contractures in children with CP are not well understood, making it difficult to determine if the theory underlying muscle stretching is correct. Second, clinical research evaluating the effectiveness of stretching techniques with children with CP is inconclusive and cannot guide therapists' clinical decision making.

In this article, we review current knowledge of both the underlying mechanisms of muscle contracture and the effectiveness of stretching strategies with children with CP. We also present the results of a survey of stretching practices conducted with pediatric physical therapists in Canada. We

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conclude with a discussion of considerations for community-based approaches to flexibility and fitness and some suggestions for directions of future research.

Mechanisms of Muscle Contracture with Children with CP

Increased muscle tone and poor selective motor control affect many children with CP and both of these impairments may contribute to decreased frequency and variety of voluntary movement.⁵ It is assumed that reduced movement contributes to a decrease in muscle belly length due to an adaptive response of the muscle involving a reduction in the number of in-series sarcomeres.⁶ However, little is actually known about the structural and mechanical changes that occur within the muscles of children with spasticity. Knowledge about the physiological mechanisms involved in contracture development has the potential to inform intervention strategies used in pediatric physical therapy.

Traditional theories of muscle contracture development were based on classic animal model studies performed in the 1970s by a group of researchers in France.⁷⁻¹² These researchers evaluated differential responses of cat and rodent muscles to immobilization in different positions. When the soleus muscles in these animal models were immobilized in a shortened position, the muscles adapted by a shortening of the muscle fibers because of a significant reduction (up to 40%) in the number of in-series sarcomeres.⁷ When the soleus muscles were immobilized in elongated positions, the muscles adapted by increasing the number of in-series sarcomeres. These studies provided evidence that the soleus muscles of these animals responded to joint immobilization by modifying the number of in-series sarcomeres. The results of these animal model studies have been extrapolated to explain human muscle response to immobilization, but there has not been rigorous evaluation of the assumption that human muscles respond similarly to the animal models.⁶ In a well-known study with children with CP, Tardieu et al¹³ observed increased muscle hypoextensibility (resistance to passive stretch) in the triceps surae muscles compared with muscles of typically developing children and concluded that decreased muscle extensibility was the result of the adaptive response (ie, reduction of the number of in-series sarcomeres) observed in the animal models. They did not, however, directly measure either muscle fiber length or the number of sarcomeres to confirm this theory of muscle contracture.

The only definitive method of determining muscle fiber length is to dissect fibers from whole muscles. For obvious reasons, this invasive technique is not used with humans.⁶ Alternate methods have been developed to measure muscle fiber length in spastic muscles of children with CP. Lieber et al¹⁴ used an intraoperative laser diffraction technique to compare the sarcomere length of the flexor carpi ulnaris muscles of individuals with wrist flexion contractures (ie, 5 children with CP and 1 adult with spasticity) and 12 participants without disabilities. Their data suggested that sarcomere length of the individuals with spasticity was increased whereas serial sarcomere number

and muscle fiber length were not different from the control group. Ultrasound has also been used to measure muscle fiber length of children with CP.^{15,16} Shortland et al¹⁶ measured the muscle thickness and deep fascicle angle (angles at which fascicles arise from the deep aponeurosis) of the medial gastrocnemii muscles of 5 adults without disabilities (24 to 36 years), 7 children with spastic diplegic CP (6 to 13 years), and 5 children without disabilities (7 to 11 years). Deep fascicle angles of the children with spastic diplegia were reduced significantly compared with the control group, but the actual muscle fiber length did not differ between the two groups. Both of these studies^{14,16} suggest that the underlying mechanism of muscle contracture is not a reduction of in-series sarcomeres. Shortland et al¹⁶ hypothesized that the gastrocnemii muscle bellies are shortened in individuals with CP because of muscle fiber atrophy rather than decreased sarcomere length or decreased number of in-series sarcomeres. Because the gastrocnemius is a pennate muscle composed of fibers that run at an angle to the force generated, a decrease in muscle fiber diameter could conceivably contribute to muscle belly shortening. Mohagheghi et al.¹⁵ used the same ultrasound technique and found that gastrocnemii muscle thickness was reduced in the involved legs compared with the uninvolved legs of 8 children with spastic hemiplegia. However, in contrast to Shortland et al, Mohagheghi et al reported that muscle fascicle lengths were reduced in the involved legs. The authors concluded that their data may support a reduction of both in-series and in parallel sarcomeres in the involved gastrocnemii of children with spastic hemiplegia.

Our understanding regarding the mechanism of contracture in spastic muscles is limited. The studies reviewed here suggest different underlying mechanisms of muscle shortening: reduction of the number of in-series sarcomeres, reduction of in-parallel sarcomeres, and muscle fiber atrophy. The traditional theory that decreased movement causes muscle shortening by reduction of the number of in-series sarcomeres supports classic stretching of the muscles, whereas the explanation of muscle fiber atrophy would indicate the use of muscle strengthening techniques to prevent or reduce contractures. If muscle fiber atrophy is associated with muscle contracture, resistance training and electrical stimulation will need to be explored as strategies for contracture treatment. More information is needed about the mechanisms of muscle contracture to guide selection of the most appropriate intervention choices.

Clinical Research on Muscle Stretching

Pin et al¹⁷ recently conducted a systematic review to summarize the evidence regarding efficacy of passive stretching with children with CP. We conducted a similar search of the literature, but expanded the search to include studies that evaluated the effects of active stretching. The search was limited to published studies, available in English and included the following electronic databases: CINAHL (1937 to June 2007), EMBASE (1988 to June 2007), MEDLINE (1950 to June 2007), PsycINFO (1985 to June 2007), and Scopus (1960 to June 2007). Search terms used

were “cerebral palsy” combined with “range of motion,” “stretching,” “contracture,” and “positioning.” One hundred eleven articles were identified and 104 studies were excluded because they were not intervention studies, participants were not children, the studies evaluated serial casting or the effects of splints and orthoses, or stretching was used in conjunction with pharmacological or surgical interventions.

The literature on passive stretching, active stretching, and therapeutic positioning is summarized in Tables 1 and 2. Each study was rated by its level of evidence (Table 1), which categorizes the strength of the study by its research design, and studies with greater internal validity (levels of evidence I–III) also received a conduct rating evaluating potential threats to internal validity (Table 2). The levels of evidence and conduct rating criteria were developed by the American Academy for Cerebral Palsy and Developmental Medicine.¹⁸ The paucity of studies and the lack of methodologically rigorous evaluation of existing studies are evident. Adequately powered, randomized controlled trials have not been conducted, and the single subject design studies have not been replicated. In addition, of the group studies included in Table 1, only 3 studies^{19,20,21} demonstrated any statistically significant treatment effects. The stretching techniques evaluated differed on the stretching time and number of repetitions, suggesting no standardization of stretching techniques. Despite the current clinical focus on functional (activity and participation level) outcomes, most of the research to date has focused on impairment level outcomes such as joint range of motion and spasticity. Only one study²² evaluated active stretching for children with CP; treatment effects were not demonstrated.

No strong conclusions about the effects of passive stretching, active stretching, or therapeutic positioning on joint range of motion in individuals with CP can be reached from this body of research. As Pin et al¹⁷ reported, the research in this area is weak because of methodological issues, small sample sizes, and the existence of only a small number of studies. In addition, there has been little attention in the research literature to the evaluation of active stretching with children with CP as demonstrated by the one study in our review that evaluated active stretching.²²

Current Stretching Practices—A Survey of Canadian Pediatric Rehabilitation Centers

We invited 46 Canadian rehabilitation centers to respond to a survey to identify stretching practices with children with CP; 26 sites responded (response rate 56.5%). The survey included questions about the prevalence of passive, active, and therapeutic positioning strategies used by therapists at each centre, the stretching parameters typically used (duration and frequency of stretches), specific muscle groups targeted, and the therapists’ goals for stretching. The therapists at each site completed the survey collaboratively, resulting in one completed survey from each participating centre.

Sites reported that therapists spend approximately 10% (median) of their time (range 5%–33%) performing stretching techniques and 15% (median) of their time

(range 1%–25%) teaching children, parents, and caregivers how to stretch. Therapists select specific stretching techniques (passive, active, or positioning) by considering a variety of factors including age of the child, severity of spasticity and contracture, perceived compliance of child and/or caregiver, tolerance and/or motivation for stretching, cognitive level of the child, functional abilities of the child as rated by the Gross Motor Function Classification System,²⁶ and the child’s environment.

Therapeutic positioning and active stretching are frequently used for the hip flexors, hip adductors, knee flexors, and ankle plantarflexors. Passive stretching was reported as a prevalent management strategy for all muscle groups, particularly the hip flexors, hip adductors, knee flexors, and ankle plantar flexors. Choice of stretching approach did not vary with age of the child. The parameters for stretching intervention varied considerably across the reporting sites. The number of repetitions for passive stretching ranged from 1 to 10 (median = 4), the length of time to hold the stretch varied from 15 to 90 seconds (median = 30). Parameters for active stretching ranged from 1 to 10 repetitions (median = 4) and 15 to 90 seconds duration (median = 21). The reasons for using stretching techniques were to (1) maintain current range of motion (all sites); (2) increase range of motion for functional tasks (all sites); (3) defer or avoid surgery (12 of 26 sites); and (4) attain full range of motion (11 of 26 sites). This small survey suggests a lack of standardization of stretching techniques. The common assumption across all sites is that stretching will maintain range of motion and may positively affect functional abilities. Many of the sites also assumed that stretching may delay or avoid surgical intervention for muscle contractures. Research studies have not confirmed these assumptions and therefore it is evident that a significant gap exists between clinical rationale for stretching and research evidence.

DISCUSSION

Our understanding of the mechanisms of contractures in spastic muscles is rudimentary. Ideally our clinical decisions should be guided by good scientific inquiry.²⁷ There is a need for laboratory research into the mechanisms of muscle contracture to provide additional information about the theoretical assumptions that guide physical therapy interventions for children with CP.

Clinical evaluation of the effects of stretching techniques is also needed because existing research evidence is not adequate to support or refute the effectiveness of stretching as a management strategy. Pediatric physical therapists have an essential role to play in this area of evaluation. The primary outcome evaluated in studies examining the effects of passive stretching in individuals with CP has been joint range of motion. Goniometric measurements are appropriate because the primary outcome expected with stretching is a change in muscle length and joint range of motion. Therapists use stretching interventions for children with CP with the assumption that the stretching program will not only assist with maintenance of joint range of motion, but positively impact

TABLE 1
Summary of Studies—Interventions, Participants, and Results

Study	Level of Evidence* and Study Design	Participants	Intervention	Outcome Measures	Results
McPherson et al ²⁴	Single subject design†	Four children with cerebral palsy (10–18 yr)	Passive stretching and therapeutic positioning Year 1: 60 sec knee extension stretch, 5 repetitions, 3×/d, 5 d/wk Year 2: prone or supine standing devices for 1 hr/d	Hip extension ROM (goniometer) for the study Muscle tone with a device specifically designed	Knee extension increased an average of 4 to 9° during the treatment periods and decreased an average of 5 to 10° during the nontreatment periods SS not tested Decrease in muscle tone during second year of study
Miedaner et al ²⁵	Single subject, randomized cross-over design	13 persons with cerebral palsy (6–20 yr) severe cognitive and physical impairments	Passive stretching 20–60 sec stretch, five repetitions, 5 d/wk and 2 d/wk	Passive hip, knee, ankle, and forefoot ROM (goniometer)	NS for six of the seven ROM measurements right popliteal angle increased following the higher frequency intervention ($p < 0.05$)
Tremblay et al ¹⁹	Level II Small RCT	21 children with spastic cerebral palsy (3–14 yr)	Passive stretch One occasion for 30 min on tilt table for ankle dorsiflexion stretch	Quality of passive ankle movement (Kin Com dynamometer and surface electrodes) Quality of triceps surae contraction (Kin Com dynamometer and surface electrodes)	Decreased resistance to passive movements up to 35 min after stretch ($p < 0.05$) Decreased EMG response during passive movements up to 35 min after stretch ($p < 0.05$)
Richards et al ²⁰	Level II Small RCT	19 children with spastic hemiplegia or diplegia (3–13 yr)	Passive stretch One occasion on tilt table 30 sec for ankle dorsiflexion stretch	Muscle activation of tibialis anterior (EMG) Gait analysis (video recording) Gait (Spastic Locomotion Disordered Index)	Improved activation of tibialis anterior ($p < 0.01$) NS NS
Fragala et al ²³	Single subject design	7 children and adolescents with cerebral palsy (4–18 yr) GMFCS levels IV or V	Passive stretching and therapeutic positioning 40–60 s, 3 repetitions, 1–2×/wk and routine positioning in classrooms (ie, use of wheelchairs, reclined seats, supine lying and side lying, Standing devices were not used)	Knee and hip extension ROM (goniometer)	No consistent changes in ROM across participants
O'Dwyer et al ²¹	Level II small RCT	15 individuals with spastic cerebral palsy (6–19 yr)	Passive stretching 30 min stretch, 3×/wk for 42 d	Contracture of triceps surae (passive torque of ankle joint)	NS
Darrah et al ²²	Level IV Cohort study without control group	23 adolescents with cerebral palsy (11–20 yr)	Active stretching Stretching program for hamstrings, quadriceps, hip adductors, internal rotators, and ankle plantar flexors (10–15 sec hold) 3×/wk for 10 wk	Spasticity of triceps surae (tonic stretch reflex) Flexibility of hamstring muscles (sit and reach test) Flexibility of hip adductors (intermalleolar distance)	Reduction in spasticity ($p < 0.025$) NS

* Levels of evidence: level I—systematic review of randomized controlled trials (RCTs) and Large RCTs with narrow confidence intervals ($n > 100$); level II—smaller RCTs (with wider confidence intervals) ($n < 100$) and systematic reviews of cohort studies and “outcomes research” (very large ecologic studies); level III—cohort studies (must have concurrent control group) and systematic reviews of case-control studies; level IV—case series, cohort study without concurrent control group (eg, with historical control group) and case-control study; level V—expert opinion, case study or report, bench research, expert opinion based on theory of physiologic research and common sense/aneecdotes.

† Levels of evidence and quality for single subject design studies are not rated in the AACPDM methodology. ROM indicates range of motion; SS, statistical significance; NS, no statistical significance; EMG, electromyogram; GMFCS, Gross Motor Function Classification System.

TABLE 2

Conduct of Study (for Levels I, II, and III Group Designs Only)

Study	Level/Quality							Total
	1	2	3	4	5	6	7	
Tremblay et al ¹⁹	Yes	Yes	Yes	No	No	Yes	Yes	5/7 (Moderate)
Richards et al ²⁰	Yes	Yes	Yes	No	No	Yes	Yes	5/7 (Moderate)
O'Dwyer et al ²⁵	Yes	Yes	Yes	No	No	Yes	Yes	5/7 (Moderate)

Conduct of the study is rated as strong (6–7), moderate (4–5), or weak (0–3).

1. Were inclusion and exclusion criteria of the study population well described and followed?
2. Was the intervention well described and was there adherence to the intervention assignment (for two-group designs, was the control exposure also described)?
3. Were the measures used clearly described, valid and reliable for measuring the outcomes of interest?
4. Was the outcome assessor unaware of the intervention status of the participants (ie, were there blind assessments)?
5. Did the authors conduct and report appropriate statistical evaluation including power calculations?
6. Were drop out/loss to follow-up reported and less than 20%. For two-group designs, was drop-out balanced?
7. Considering the potential within the study design, were appropriate methods for controlling confounding variables, and limiting potential biases used?

the functional abilities of the child. Many therapists also use stretching to avoid or delay the development of secondary complications. The current body of research on stretching does not include any investigation of the relationship between changes of joint range of motion and changes in functional abilities or need for surgery. The International Classification of Functioning, Disability and Health (ICF)²⁸ explicitly cautions against assuming a direct relationship between factors at the component of body function and structure (eg, range of motion, spasticity) and changes at the component of activity (eg, dressing or riding a bike) and participation (e.g. integration in classroom activities). For example, maintaining a child's hamstring length may not make it any easier for him to get on and off the school bus (activity) or to participate in gym class at school (participation). A recent study evaluated the interrelationships among muscle tone, passive range of motion, selective motor control, and gross motor function in a group of children with CP and reported only a modest relationship between motor impairments and participation in everyday activities.²⁹ It is essential that future research includes the evaluation of the relationships among outcomes representing body functions and structures, activity and participation to determine both the physiological and functional outcomes of stretching programs, particularly because enhancing functional abilities is one of the reasons why therapists use stretching as a clinical intervention.

Another reason to consider alternative outcomes is the documented measurement error of goniometry with children with a diagnosis of CP. McDowell et al³⁰ reported significant variability with measurements errors as high as 14° for 3 of the 6 range of motion measurements with 12 children with spastic diplegia. Other researchers have also reported significant measurement error using goniometry to measure joint range of motion with children with CP.^{31–33} Researchers need to consider more precise ways of measuring joint range of motion and the use of different outcome measures to document changes in children's functioning.

Passive stretching is, by its very nature, a "passive" technique that is done without the child's participation. Isolated active stretching and positioning practices such as

prone lying and stretching hamstrings in long sitting are also not particularly fun for the child or family. Parents may be hesitant to use traditional stretching techniques as they may be uncomfortable for their children³⁴ and they may already be overwhelmed by a number of other interventions their children require. Contemporary approaches to rehabilitation for children with CP are changing to include community participation, fitness, and functional goals^{35–37} and therapists are challenged to explore innovative management approaches that reflect these values. Perhaps the focus on maintaining joint range of motion needs to change to an emphasis on maintaining flexibility and encouraging the exploration and maintenance of a variety of movement options. All children, including children with physical disabilities, need to have opportunities to engage in physical activities that will enhance their levels of physical fitness. They also need opportunities to participate in fun activities with other children. From this perspective, the emphasis on joint range of motion changes to a focus on encouraging movement opportunities that enable children with CP to experience a repertoire of movement experiences and participate in enjoyable activities while enhancing their physical fitness. Therapists may want to consider activities such as yoga, Tai Chi, horseback riding, ballet, and swimming programs that allow children to stretch and move within a functional, participatory context. Through such programs, children with CP could become active participants in fitness programs that encourage flexibility instead of passive recipients of therapeutic stretching routines. Therapists can use their expertise to identify innovative flexibility options that are enjoyable for everyone and will lead to life long fitness opportunities for the child.³⁸

Physical therapists possess the knowledge of development, movement, and CP to assist children and adolescents with CP to participate in community fitness programs. Therapists can play an important role in the development of transitional programs in rehabilitation centers, in which typical fitness programs are adapted to meet individual movement abilities. Therapists can also help families to identify community programs and provide support for the

transition to these programs. Therapists can work with families and community fitness facilities to encourage children and adolescents with CP to integrate flexibility exercises into their regular fitness routines and to modify program content so that children and youth with motor disabilities can participate effectively and safely. Our experience with a community-based fitness program for children and adolescents with CP²¹ convinced us that community fitness programs are a viable alternative to medically oriented therapy programs. It is an exciting time in pediatric rehabilitation and an ideal time for therapists to use their creativity, knowledge, and skills to develop innovative and fun strategies to integrate therapy with fun physical activities and to contribute to the rigorous evaluation of stretching strategies used in pediatric rehabilitation.

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