Management of Diaplegic Cerebral Palsy via Continuous Passive Movement

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ABSTRACT

***Background and Purpose**: Continuous passive motion (cyclic stretching applied to the child's back) has been used for the rehabilitation of some pediatrics impairments; however, few researchers have considered its application in the management of neurological disorders such as stroke. The purpose of this study was to examine the short-term effects of prolonged continuous passive movement on torque relaxation, and gait in children with diaplegic cerebral palsy. **Subjects**: Ten spastic diaplegic cerebral palsied children (mean age = 6.65±1.76 years, range from 5-8) who were volunteered to be subjects. **Methods**: Participants engaged in one 30-minute static stretch and one 30-minute cyclic stretch of the back muscle, using continuous passive movement machine. Before and after treatments, ten meters walking times were collected. Ankle joint stiffness was calculated from the slope of the torque and angle curves before and immediately after treatments, and torque relaxation was calculated as the percentage of decrease in peak passive torque over the 30-minute stretch durations. **Results**: Ankle joint stiffness decreased by 35% and 30% after the static and cyclic stretches, respectively. Stiffness values and 10-m walk times were not different between conditions. The amount of torque relaxation was 53% greater for static stretching than for cyclic stretching. **Discussion and Conclusion**: These preliminary data from the sample of children with spastic diaplegia indicate that ankle joint stiffness decreases after both prolonged static and cyclic stretches; however, neither technique appears to be better at reducing stiffness in children with spastic diaplegia. Torque relaxation is greater after static stretching than after cyclic stretching, and walking speed does not appear to be influenced by the stretching treatments used in our study.*
***Key words:** Continuous passive movement, Rehabilitation, Spasticity.*

INTRODUCTION

Children who have experienced a spastic diaplegic cerebral palsy may exhibit an increased resistance to passive joint movement, decreased joint range of motion, and some exaggerated stretch reflexes. Researchers and clinicians have frequently described some of these symptoms as components of spasticity, defined as "a motor disorder characterized by a velocity-dependent increase in tonic stretch reflexes with exaggerated tendon jerks, resulting from hyper-excitability of the stretch reflex"[1].

The definition of spasticity implies that an increase in motoneuron response to muscle lengthening may be the primary mechanism for these symptoms of diaplegic cerebral palsy[2]. Although evidence for increased motoneuron excitability is strongly supported[3,5], some researchers[6,9] have argued that changes in passive mechanical properties of muscle may be the additional mechanisms responsible for symptoms observed in people with spasticity.

Passive mechanical properties of muscle (i.e., how the muscle responds to applied loads) are related to the amount, type, temperature, and organization of structures such as muscle, collagen, elastin, proteoglycans, and water[10]. The mechanical properties are typically expressed as stiffness, which is the relationship between passive resistive torque and joint displacement, and torque relaxation, which is the decrease in peak passive torque (passive resistance) exhibited at a joint held in a non-neutral position over time[11,13], Studies have shown that, in patients with spasticity, passive mechanical properties of muscle are to some extent responsible for impaired gait patterns[6,7,14] and enhanced passive joint resistance[9,15]. In our opinion, these findings suggest that interventions for spastic diaplegic cerebral palsy may need to focus on passive mechanical properties of muscle and not just motoneuron excitability.

Approaches for treating symptoms related to spasticity following spastic diaplegic cerebral palsy range from the use of modalities (e.g., biofeedback) to complex neurosurgical procedures (e.g., dorsal rhizotomies). There is, however, no consistent definition for spasticity. Therefore, these interventions may not always be aimed at decreasing the same symptoms. One common intervention that is used with most approaches is prolonged static stretching[16,18]. Investigators[16,18,21] have shown that stretching of the back muscles for periods ranging between 30 minutes and 6 weeks, reduced passive ankle joint resistance, increased ankle joint range of motion, and improved gait characteristics (e.g., stride length, stride width, angular joint displacement). Some researchers[22,23] have argued that the effects of static stretching are proportional to the amount of time a stretch is held at its end-range. Accordingly, some authors[18,20] have suggested that prolonged static stretching rather than short-term stretching (e.g., < 2 minutes) can be a convenient and cost-effective means of reducing symptoms of spasticity.

Research has indicated that continuous passive motion (i.e., cyclic stretching) about the back muscles may be more effective in reducing passive ankle joint stiffness than static lumber fascia stretching[11,24]. McNair and coworkers[**11**] examined passive ankle joint stiffness in volunteers without impairments after a single 60-second static lumber fascia stretch and after a 60-second cyclic lumber fascia stretch to determine the efficacy of the 2 stretching techniques. They reported a 16% decrease in ankle joint stiffness after cyclic stretching and no difference in stiffness after static stretching. Their findings supported earlier work[**24**] that showed ankle joint stiffness was more effectively decreased by cyclic movement in spinal muscles than by static stretching exercises, which suggests that cyclic motion may be more effective than static holds at decreasing stiffness at the ankle joint. Cyclic stretching also may increase joint range of motion according to Taylor et a[l25], who used an in vitro model.

Although cyclic stretching has been an accepted approach for the rehabilitation of some orthopedic problems (e.g., total joint arthroplasty, contracture)[26], few researchers have considered its application in neurological disorders such as cerebral palsy[27]. The purpose of our study, therefore, was to compare the short-term effects of prolonged static and cyclic calf stretching of spinal muscles on passive ankle joint stiffness, torque relaxation, and gait in children with spastic diaplegia who exhibit increased resistance to passive joint movement, decreased joint range of motion, and exaggerated stretch reflexes. We believe the results of our study may be clinically meaningful if cyclic stretching is more effective than static stretching in reducing the symptoms of spastic diaplegia in children.

SUBJECTS, INSTRUMENTATION AND PROCEDURES

Subjects

Ten children (9 male and 1 female) who were diagnosed as spastic diaplegic cerebral palsy volunteered for this investigation. Their age was ranging from 5 to 8 years with 6.65 years mean value. The diagnoses were made by a neurologist, and patients records did not include the criteria used for the diagnoses of cerebral palsy. The subjects were recruited from the out-patient clinic at the Faculty of Physical Therapy, Cairo University. We hypothesized that a 10% difference in passive stiffness between stretching conditions would be clinically relevant.

Participants were included in the study if they met the following criteria: (1) They were not taking anti-spasticity medication, (2) They were free from contractures, (3) They had the mental capacity to perform the experimental tasks, (4) They were ambulatory with or without assistive devices, and (5) they had sufficient ankle range of motion to perform the experimental task. The degree of spasticity ranged from mild to moderate grades using a modified Ashworth Spasticity Scale[28]. Ankle jerk response and plantar response were evaluated and characterized. The subjects' physical characteristics are shown in table (1), and a description of the assessments is reported in the table (2).

Table (1): Physical characteristics of subjects with spastic diaplegic cerebral palsy.

Child No.	Age (Y)	Sex	Ankle Jerk Response[(a)]	Planter Response[(b)]
1	7	M	++	-
2	6	M	++++	+
3	5	M	++	+
4	5.5	M	++++	-
5	6	M	+++	+
6	7	F	+++	+
7	8	M	++	-
8	7.5	M	++	-
9	8	M	++	-
10	6.5	M	++	-
Mean	**6.65**	**------**	/////	/////
SD	**±1.76**	**------**	/////	/////

(a) Ankle jerk response: 0= no response, += diminished/ slight response, ++= normal, +++=marked response, ++++=severe response.
(b) Planter response: -= negative, += positive.

Instrumentation

*** For evaluation**

1- Kin-com dynamometer.
2- Electromyography.
3- Electrogoniometer.
4- Hammer.

*** For treatment**

1- Continuous passive movement machine (back-life)(Fig.1).
2- Balls, wedges and rolls.

Fig. (1): Continuous passive movement machine.

Procedures

Children attended a preliminary test session (Table 2) that included the measurement of physical characteristics and maximal dorsiflexion angle. Subjects relaxed in a supine position with their knees fully extended while their foot was passively moved from 10 degrees of plantar flexion into dorsiflexion until "firm" resistance was displayed[29] or the subject reported feeling discomfort.

Table (2): Assessment measures used in the study.

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Mini- Mental State Examination: examines cognitive aspects of mental health. Subjects responded to series of assessments that include Orientation, memory, naming verbal instruction, and written commands[27]. Scores range from 0 to 30, with 30 indicating no errors at the test. A score of 20/30 was used in this study to distinguish between people with cognitive impairments and people with "normal" levels of cognition.

Modified Ashworth Scale: grades the passive resistance (or tone) encountered at a joint during a passive stretch. The 5 - point scale ranges from 0 (no muscle tone) to 4 (limb is rigid in flexion or extension)[28] .

Ankle Jerk Response: tests for hyperreflexia. The ankle jerk response was elicited by tapping the Achilles tendon with a reflex hammer to produce a sudden stretch of the plantar-flexor muscle tendon unit The response was graded as no response, diminished / slight, normal, marked , or severe depending on the plantar- flexion response.

Plantar Response: tests for hyperreflexia. The plantar response was elicited by moving a fingertip up the lateral side of the foot from the heel to the base of the little toe (digit 5) then across the ball of foot. The response was graded as "positive" when digit 1 (great toe) plantar flexed or "negative" when digit 1 extended and digits 2 to 5 abducted. A positive test is considered normal.

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Children attended two experimental test sessions that were separated from each other by one week and were conducted at the same time of the day. Subjects were instructed not to begin a stretching program between test sessions, and they were told to reschedule their session if there were symptoms prevented testing. During the first test session, participants engaged in either a 30-minute cyclic stretching protocol or a 30-minute static stretching protocol. Subjects were randomly assigned to the 2 groups and performed the protocol on their involved lower extremity. The stretching protocol that was not performed during the first test session was performed during the second test session. The 30-minute stretch duration was chosen for comparative purposes and because it has been previously shown to reduce passive ankle joint resistance and motoneuron excitability of the triceps surae muscle and to increase ankle joint range of motion[16,18,20].

For the 30-minute static back stretching protocol, the subject's lower limbs were held at a rate of 90 degrees of hips flexion to a static hold at 100% of the participant's maximal passive hip flexion angle. Immediately following the static stretch, the lower limbs were returned to neutral, then back to 100% of maximal hip flexion angle, and again returned back to neutral. The last stretching sequence was necessary so that measurements of stiffness before the stretch could be compared with measurements of stiffness after the stretch.

For the 30-minute cyclic back muscles stretching protocol, continuous passive motion for the lumber area using continuous passive movement machine (back-life) was performed. The angular velocity and end-ranges of motion selected for the static and cyclic stretching protocols have been shown in some subjects with spastic cerebral palsy and volunteers without impairments to not evoke a stretch reflex and to improve subject relaxation[11,30].

During the stretching protocols, the participants were asked to lie in a supine position with their foot strapped to a footplate connected to a Kin-Com dynamometer. The Kin-Com dynamometer is a computerized device that was programmed to manually move the foot according to the stretching protocols and to collect force and angle measurements by electrogoniometer. The signals from the potentiometer and load cell of the Kin-Com dynamometer were sampled simultaneously at 500 Hz and stored for subsequent analyses using a computer. Previous studies[30,31] have shown that under selected conditions the Kin-Com dynamometer provides measurements that we would consider reliable and valid for ankle joint angle and passive torque.

Electromyographic (EMG) activity was monitored in an effort to ensure that passive torque measurements were not influenced by voluntary or involuntary muscle activity. The EMG signals were recorded with bipolar surface electrodes placed over the tibialis anterior and lateral gastrocnemius muscles. A ground electrode was placed around the ankle joint. Standardized techniques for surface electrode preparation and placement were used[32]. The EMG signals were recorded for 10 seconds, sampled at 500 Hz at a bandwidth of 20 to 450 Hz, and amplified using amplifier. The EMG signals were collected at 1-minute intervals beginning with the initial movement of the foot into dorsiflexion. The root mean square of the EMG data was calculated[32] and normalized to reflect a percentage of maximal voluntary contractions (MVCs). Subjects performed MVCs of the plantar flexors and dorsiflexors with their feet held in 10 degrees of plantar flexion, using the Kin-Com dynamometer. The subjects performed 3 maximal efforts, with verbal encouragement from the investigator. The data of subjects exhibiting EMG values greater than 1% of the MVC during the passive measurements were not used for the data analysis.

Gait was assessed by having participants complete a 10-m walk test before and after treatments at a "comfortable speed." Walking speed is one of the most widely accepted measures of lower-limb recovery[33.] The intention of including a 10-m walk test in this study was to test the immediate effect of stretching treatments on a functional outcome measure. The average time of 3 walking trials was used for subsequent analyses[34].

Data Analysis

We defined passive joint resistance as resistive torque exerted through the foot by, among other structures, the plantar-flexor muscle-tendon unit, and it was calculated from the force data taken from the Kin-Com's load cell and the moment arm length. Moment arm length was defined as the distance from the lower edge of the load cell to the lateral malleolus and corresponded to 0.2 m.

Mean stiffness was calculated before and after treatments from the slope of the torque-angle curve (∆ torque/∆ angle) for the initial and final movements of the foot into dorsiflexion (i.e., from neutral to 80% of the subject's maximal passive dorsiflexion angle). Torque relaxation was calculated from measurements of initial peak torque and final peak passive torque taken during the 30-

minute static and cyclic back stretching protocols.

The within-subject design of this study included 2 independent variables (stretching protocol and treatment time) and 3 dependent variables (mean stiffness, percentage of torque relaxation, and 10-m walking times). Given the number of dependent variables, we used a multivariate Hotelling T^2 procedure to determine the effect that cyclic and static stretching had on the group of dependent variables. If the main multivariate effect for group was statistically significant, a Wilcoxon signed rank test value was then calculated for each dependent measure. Given the high variability expected among subjects, we chose to analyze differences between conditions with the Wilcoxon nonparametric test. The probability associated with a Type I error was set at .05 for all observations.

RESULTS

All subjects underwent testing as planned, and no subjects exhibited an EMG value greater than 1% of MVC. Therefore, data from all subjects were included in the analyses. The Wilks' criteria for the Hotelling T^2 procedure revealed that the combined group of dependent variables were affected by stretching protocols ($P<.001$) and treatment time ($P<.001$). Follow-up univariate statistics showed that mean ankle stiffness values were different after static and cyclic stretching, whereas no differences were observed between conditions (Table 3 and Fig.2). Stiffness values decreased by 35% and 30% after static and cyclic stretching respectively.

The amounts of torque relaxation were different between conditions ($P<.01$). The amounts of torque relaxation are reported in Table 3 and fig. (3) which were 53% greater for static stretching than for cyclic stretching. Univariate analyses of mean walking times revealed no main effect within or between conditions (Table 3 and fig. 4).

Table (3): Comparison of dependent variables within and between prolonged static and cyclic stretching.

	Pre-stretch Values				Post-stretch Values			
	Static		Cyclic		Static		Cyclic	
Variable	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Ankle Stiffness (°)	1.50	0.42	1.54	0.61	0.98	0.33	1.08	0.44
t-test and P Value	2.87(P<0.05)				4.66(P<0.001)			
Torque relaxation (%)	///	///	///	///	35.12	2.44	23.02	8.75
t-test and P Value	///				4.563(P<0.01)			
10-m Walk times(s)	20.25	11.89	20.16	12.07	20.70	12.08	20.24	12.22
t-test and P Value	1.23(P>0.05)				1.45(P>0.05)			

$\bar{X}$: Mean SD: Standard deviation (%): Percentage (s): Seconds

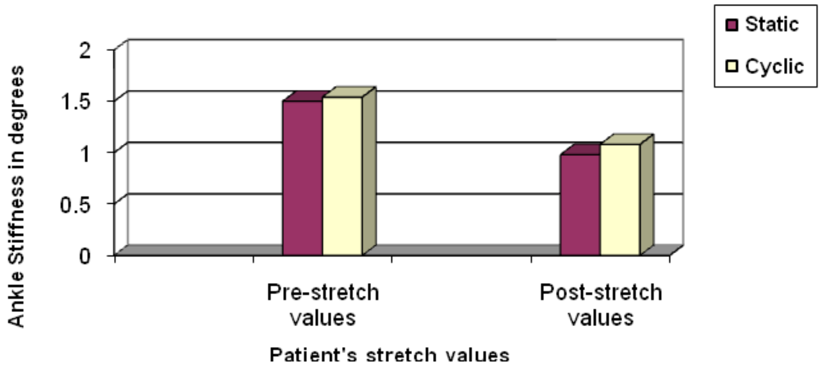

Fig. (2): Mean ankle stiffness values(degrees) before and after treatments.

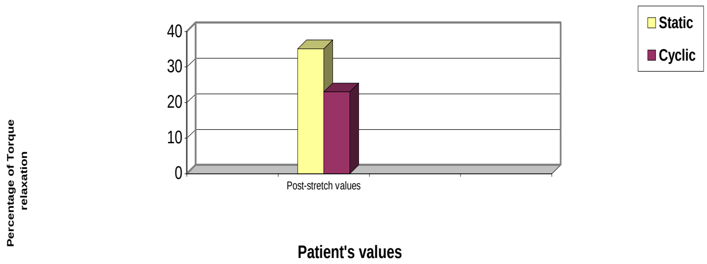

Fig. (3): The mean values of Torque relaxation in percentage post-stretch.

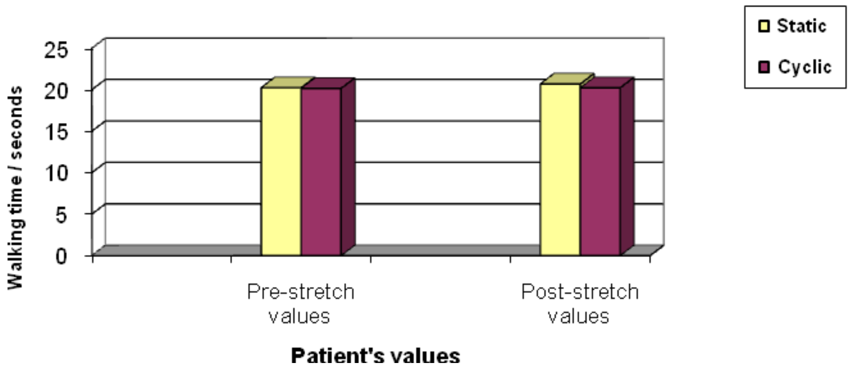

Fig. (4): The mean values of walking time in seconds pre and post stretch.

DISCUSSION

Previous research[11] has suggested that cyclic stretching about the lower back muscles may be more effective than static stretching at decreasing spasticity in lower limbs. A comparison of stretching interventions has not been examined in children with cerebral palsy, where the potential benefits of decreased spasticity might be considered highly desirable. An aim of our investigation, therefore, was to compare the short-term effects of prolonged static and cyclic lower back stretching on passive ankle joint stiffness in children with spastic diaplegia.

Stiffness values decreased after prolonged static stretching, and we found this consistent with the passive torque data reported by Tremblay and coworkers[20]. Our results also support the contention that prolonged static stretching is effective at reducing symptoms of spasticity such as passive joint resistance[16,20]. Our results further suggest that prolonged cyclic stretching may be equally effective as prolonged static stretching at decreasing ankle joint stiffness (Table. 3).

According to Enoka[35], a mechanism by which stiffness may decrease after a passive static or cyclic stretch is related to the thixotropic property of muscle. Thixotropy has been defined as the physical change of a substance after being mechanically agitated[36,37]. For example, a gel substance such as ketchup may become less viscous (i.e., more fluid) if mechanically agitated[35]. In this study, the gel component of muscle (e.g., water and proteoglycans) may have become less viscous after being stretched, resulting in less passive stiffness. Indeed, for this scenario to be plausible, the muscle must not receive neural input because this may also modulate stiffness. Because EMG activity was less than 1% of the MVC during the conditions of our study, we do not consider neural mechanisms as contributing to the passive mechanical measures.

In general, our stiffness values were greater than those reported for people without a stroke[12,38] and are consistent with data reported by other researchers[9,15]. Vattanasilp et al[15] investigated factors contributing to muscle stiffness after stroke, including thixotropy and contracture. They concluded that contracture was a major contributor to exaggerated ankle joint stiffness and that thixotropy was not different in patients with stroke versus subjects without impairments who were in a control group. Their results[15] and ours showing greater passive stiffness may provide further evidence to support the research of Dietz et al[39] that indicated a morphological and not just a motoneuron transformation of spastic muscle over time.

Our results, which showed no difference in stiffness between stretching conditions, do not agree with the results of previous work examining the effect of short-term stretches (e.g., 60 seconds) in people without impairment[11]. McNair and coworkers[11] suggested that thixotropic properties of muscle (e.g., collagen, water, proteoglycans) may become less viscous during cyclic motion than during static stretching because of the continuous nature of the cyclic stretch. In our study, constituents of muscle that contribute to thixotropy may not have responded the same as they did in children without impairment, and this may be due in part to the condition of the patients' tissues as a result of their lesion.

An additional purpose of our study was to compare the effect of prolonged static and cyclic lower back muscles stretching on torque relaxation. The patterns of decline in torque between these 2 modes of stretching were similar to those of previous research[11]. McNair and coworkers[11] reported 17% and 11% declines in torque over 60-second static and cyclic stretches, respectively, at the lower back. The difference in torque relaxation between stretching modes (i.e., 54%) that they observed corresponds to the 53% difference we observed. Torque relaxation values were substantially greater in our study (23%-35%), probably because of the prolonged stretch duration (60 seconds versus 30 minutes). Theoretically, the torque relaxation response could continue indefinitely because of the viscoelastic properties of biological tissues[25].

Our static stretch data supported this contention and continued to decline up to 30 minutes, whereas no appreciable decreases were observed after the initial 15 to 20 minutes of the cyclic stretching condition. On the basis of these findings and those of other researchers[11], it appears, in our opinion, that static stretching may be more effective than cyclic stretching at decreasing peak passive torque in children with spastic diaplegia.

It is important to examine whether an intervention is useful to the patient and therapist. Researchers[19,21], have shown that long-term static stretching of the lumber region (>30 minutes), using a casting, improved characteristics of gait in subjects with spastic cerebral palsy. In our study, we used a common measure of mobility (i.e., 10-m walk times) and found no improvement after or between stretching interventions (Table 3). These data imply that neither the 30-minute cyclic intervention nor the 30-minute static stretch intervention may improve gait speed after a one-time treatment.

The results of our study concern the immediate effects after a one-time 30-minute stretch intervention. We did not measure any long-lasting effects. Researchers in this area, in our opinion, should compare the lasting effects of each treatment after a training period. This would be more clinically relevant. We believe it may also be of value to assess force measurements before and after interventions, because there is recent evidence to support 12% and 25% decreases in MVC of the quadriceps femoris and plantar-flexor muscles, respectively, after a prolonged 20- to 30-minute passive stretch in volunteers without impairments[40,41].

Reduced strength of the quadriceps femoris and plantar-flexor muscles of children with spastic diaplegia may further decrease performance on selected functional outcomes such as gait because of their already weakened condition.

Ankle joint stiffness decreased after both prolonged static and cyclic stretching, although neither technique appeared to be better at reducing stiffness in children with spastic diaplegia. Torque relaxation was greater after static stretching than after cyclic stretching, and walking speed did not appear to be influenced by the stretching treatments used in this study.

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الملخص العربى

علاج الشلل المخي عن طريق الحركة السلبية المستمرة

الخلفية والغرض: الحركة السلبية المستمرة إستعملتْ لإعادةِ تأهيل حالات طبِ الأطفال؛ على أية حال، فقد تم تطبيقِه في علاج الاِضطراباتِ العصبيةِ مثل الفالج الشقي. غرض هذه الدراسةِ كَانتْ أَنْ تَفْحصَ التأثيراتَ القصيرة الأمدَ للحركةِ السلبيةِ المستمرةِ المطوّلةِ على إرخاءِ عزم العضلات، والمشية في الأطفال المصابينِ بالشلل المخي. عينة البحث: عشرة أطفال من المصابين بالشلل المخي تراوحت أعمارهم بين خمسة وثمانية أعوام . طريقة البحث: خضعت عينة البحث إلي ثلاثون دقيقة للشد الثابت لمنطقة أسفل الظهر وكذلك إلي ثلاثون دقيقة أخري للحركة السلبية المستمرة لعضلات الظهر وتم قياس بعض المتغيرات مثل السير لمدة عشرة أمتار وكذلك تم قياس درجة تيبس مفصل القدم ودرجة عزم الارتخاء العضلي. النتائج والتوصيات: أظهرت النتائج وجود فروق ذات دلالة إحصائية بالنسبة للمتغيرات القياسية. ونوصي باستخدام الحركة المستمرة السالبة مع الشد في علاج حالات الأطفال المصابين بالشلل المخي .