Efficacy of Shock Wave Therapy on Spasticity and Hand Function in Children with Cerebral Palsy

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ABSTRACT

This study was conducted to investigate the effect of shock wave therapy on spasticity and hand function in children with spastic cerebral palsy. Thirty children with ages ranged from 5 to 7 years participated in this study. They were randomly divided into experimental and control group. The experimental group received shock wave therapy on forearm and wrist flexors 800 shocks/muscle, frequency 10 Hz, energy 0.03 mJ/mm^2 one session/week and conventional physical therapy for a successive 3 months. Those in the control group received the same conventional physical therapy only. They were evaluated before and after the treatment by using the Modified Ashworth Scale and the Peabody Developmental Motor Scale, respectively. The results revealed a statistically significant improvement spasticity and hand function after treatment. It was concluded that shock wave therapy is effective in reducing the upper limb spasticity and improve hand function in children with cerebral palsy.

Key words: *Shock Wave Therapy; Spasticity; Hand Function; Cerebral Palsy.*

INTRODUCTION

Cerebral palsy represents a heterogeneous group of disorders caused by non-progressive disturbances of the developing brain, leading to dysfunction of movement and postural development[2]. The motor impairment in cerebral palsy is multifactorial and it includes problems such as spasticity, dystonia, muscle contractures, bony deformities, coordination problems, loss of selective motor control and muscle weakness[7].

Spasticity is a widespread problem in cerebral palsy as it affects function and can lead to musculoskeletal complications. It occurs as a result of pathologically increased muscle tone and hyperactive reflexes mediated by a loss of upper motor neuron inhibitory control[5].

Children with cerebral palsy demonstrate poor hand function due to spasticity in the wrist and finger flexors. Thus spasticity in the flexor muscles of the upper limbs poses a great deal of functional limitation in the hands. One common problem associated with poor hand function as a result of spasticity is the inability of the child to grasp objects and difficulty with fine motor tasks such as writing or cutting with hands[20].

Shock waves are defined as a sequence of single sonic pulses characterized by high peak pressure (100 MPa), fast pressure rise (<10 ns), and short duration (10μs) is conveyed by an appropriate generator to a specific target area with an energy density in the range of 0.003-0.890 mJ/mm^2. Different studies and clinical experiments have demonstrated the efficacy of shock waves in the treatment of bone and tendon diseases, including pseudoarthrosis[19], calcific tendinitis of the shoulder[9,16], epicondylitis[18], plantar fasciitis[17], and several tendon diseases, especially in athletes[14], two recent papers examined their efficacy on spasticity in adult and pediatric patients[10,26].

With regards to adult patients, Manganotti and Amelio[10] reported that a single treatment of shock wave therapy focused on flexor hypertonic muscles of the forearm and the interosseus muscles of the hand in patients with stroke resulted in a significant reduction of muscle tone that lasted for over three months. In regards to pediatric patients, the same researchers described that a single session of shock wave therapy focused on plantar flexors in children affected from cerebral palsy with spastic equinovarus foot produces a significant long-lasting (>12 weeks) reduction in muscle tone[26].

Even if the therapeutic mechanism of shock wave therapy on spastic muscles still remains unclear, the authors suggested that a direct effect on the fibrosis and rheologic

components of the hypertonic muscles has to be considered, in accordance with the therapeutic effects documented on bone and tendon disease[9,15,17,18,22,23].

The aim of this study was to determine the effects of shock wave in reduction of spasticity and improving hand function in spastic cerebral palsy.

SUBJECTS, MATERIAL AND METHODS

Subjects

Thirty children with spastic cerebral palsy (14 diplegia and 16 quadriplegia), with ages ranged from 5 to 7 years, participated in this study after their parents signed consent forms for their children's participation. They were selected from the outpatient clinic of the Faculty of Physical Therapy, Cairo University. The children were enrolled in this study if they met the following criteria: a mild to moderate degree of spasticity in the elbow and wrist flexors; ranged from grade 1+ to grade 3 according to the Modified Ashworth Scale[15]; able to sit alone or even with support; sufficient cognition to allow them to follow simple verbal commands and instructions during assessment and treatment. Children were excluded from the study if they had fixed contractures or deformities in the upper limb, concurrent therapy with oral antispastic drugs, previous treatment with botulinum toxin injection, alcohol or phenol into upper limbs, previous surgical intervention in the upper limbs, visual or auditory defects or autistic features. The study was approved by the ethical committee of the Faculty of Physical Therapy, Cairo University.

Materials

1- Modified Ashworth Scale (MAS): Was used for assessment of the degree of spasticity in the elbow and wrist flexors.
2- Peabody Developmental Motor Scale (PDMS-2): Was used to evaluate fine motor skills including grasping and visual motor.
3- Shock wave Instrumentation and treatment: An electromagnetic coil lithotripter (Modulith SLK® by Storz Medical AG) provided with in-line ultrasound, radiographic and computerized aiming (Lithotrack® system) was used. (Figure 1).

Fig. (1): Shock wave therapy equipment.

Methods

Evaluation procedures

Each child was evaluated for degree of spasticity and fine motor skills before the treatment (pre-treatment) and at the end of 3 months of treatment (post-treatment) by the same examiner who was blinded regarding the group to which each child was assigned.

Spasticity was assessed by using Modified Ashworth Scale to quantify the degree of spasticity in the elbow and wrist flexors for all children in both groups. The degree of spasticity ranged from grade 1+ to grade 3 according to Modified Ashworth Scale. To accommodate the "1+" modification for numeric analysis, grade "1+" was recorded as 1.5[6].

The Peabody Developmental Motor Scale (PDMS-2) was used to evaluate fine motor skills including grasping and visual motor integration. This scale provides a comprehensive sequence of gross and fine motor skills, by which the therapist can determine the relative developmental skill level of a child, identify the skills that are not completely developed and plan an instructional program that can develop those skills.

Treatment procedures

Physical and occupational therapy program: All children participating in this study received the same physical and occupational therapy program lasting for one hour/session, 3 times/week / successive 3 months. This program included manual passive stretching for elbow and wrist flexors, hand weight bearing exercises for both upper limbs, the protective extensor thrust was provided to stimulate the extensor pattern of the upper limbs. Furthermore, strengthening exercises for the antispastic muscles (elbow and wrist extensors) using different toys and motivation to encourage the child to perform the desired exercises, were also part of our program. Exercises facilitating hand skill patterns included basic reach, grasp, carry and release and the more complex skills of in-hand manipulation and bilateral hand use. The child sat on a chair-table and the therapist sat at the side to guide and assist the child to perform the exercises correctly.

Shock wave treatment: The pressure pulses were focused on the flexor spastic muscles of the forearm and on the interosseus muscles of the hand: 1500 shots were used to treat flexor muscles of the forearm mainly in the middle of the belly, and 3200 shots for interosseus muscles of the hand (800 for each muscle) one session/week. The energy applied was 0.03 mJ/mm^2 and frequency was 10 Hz. Different points of application were used in order to treat several areas in the hypertonic muscles. Because low energy is used, the therapy is painless and does not require any kind of anesthesia or the use of analgesic drugs. The shock wave treatment was performed over the flexor ulnaris, flexor radials, and over intrinsic muscles of the hand using the ultrasound device and pointer [10].

Statistical Analysis

Statistical analysis was performed using SPSS version 16.0. Descriptive statistics of mean and standard deviation presented the children's ages, Modified Ashworth Scale scores, and fine motor quotient (FMQ). Differences between and within groups of the pre- and post-treatment values were assessed using Student's t-test. The significance level was set at (0.05).

RESULTS

The collected data of the current study were statistically analyzed to examine the effects of shock wave therapy on spasticity and hand function in spastic children. Thirty spastic cerebral palsy children were studied. They were randomized divided into two equal groups; experimental group and control group.

Experimental group consisted of 15 children with spastic cerebral palsy (ten boys and five girls), nine with diplegia and six with quadriplegia. Their mean age was 5.67 ± 0.72 years. They received shock wave therapy on forearm and wrist flexors muscles in addition to the conventional physical and occupational therapy program. The control group consisted of 15 children with spastic cerebral palsy (eight boys and seven girls), nine with diplegia and six with quadriplegia. Their mean age was 5.87 ± 0.74 years. They received the same physical and occupational therapy program only. General characteristics of both groups were illustrated in table (1).

Table (1): General characteristics of control and experimental group.

Item	Control Group	Experimental Group
Age	5.87 ± 0.74 years	5.67 ± 0.72 years
Sex	Eight boys and seven girls	Ten boys and five girls
Type	Nine diplegia and six quadriplegia	Nine diplegia and six quadriplegia

Spasticity

Comparison of the pre and post-treatment Modified Ashworth Scale scores for experimental group revealed a significant reduction in spasticity (P= 0.001). Comparison of the pre- and post-treatment Modified Ashworth Scale scores for control group showed a significant reduction in spasticity (P = 0.017). The analysis between the groups, showed no significant difference in the

spasticity scores pre-treatment (P = 0.731), while there was a significant difference in the spasticity scores post-treatment in favor of experimental group (P = 0.009) as shown in (Table 2) and (Figure 2).

Table (2): Statistical analysis of Modified Ashworth Scale scores within each group and between groups.

Item	Pre X± SD	Post X± SD	P-Value
Control Group	2.27±0.56	1.86±0.22	0.017
Experimental Group	2.34±0.48	1.63±0.23	0.001
P- Value	0.731	0.009	

X: Mean SD: standard deviation

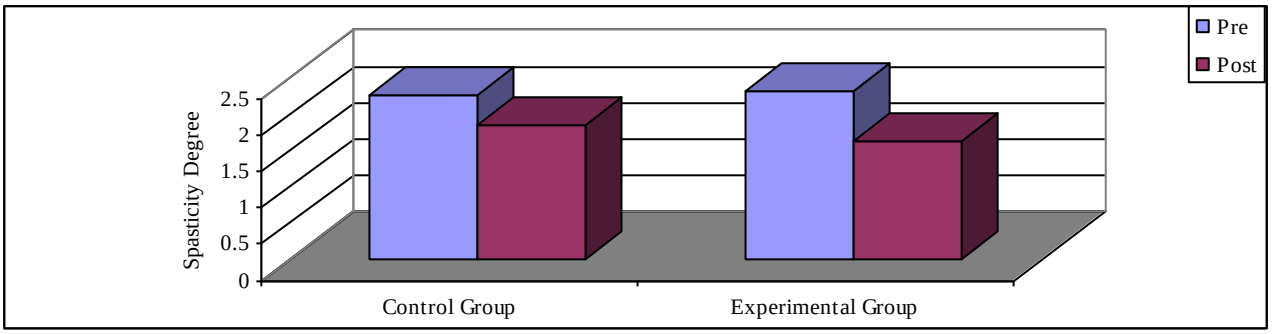

Fig. (2): Pre and post mean values of spasticity degree in both groups.

Hand function

The Peabody Developmental Motor Scale was used to evaluate the hand function for children in this study. Fine Motor Quotient (FMQ), which is the most reliable score yielded by this scale, was used to measure the changes in hand function (grasping and visual motor integration) after our intervention. Comparison of the pre and post treatment values of FMQ, revealed a significant improvement in both groups (P <0.001). The analysis of FMQ values pre and post-treatment between the groups, revealed no significant difference in pre treatment results (P = 0.456), while there was a significant difference in the post-treatment results in favor of experimental group (P = 0.0001) as shown in (Table 3) and (Figure 3).

Table (3): Statistical analysis of FMQ (Hand function) within each group and between groups.

Item	Pre X± SD	Post X± SD	P-Value
Control Group	45.93±0.70	49.40±0.63	0.001
Experimental Group	46.13±0.74	53.13±0.74	0.001
P- Value	0.456	0.0001	

X: Mean SD: standard deviation

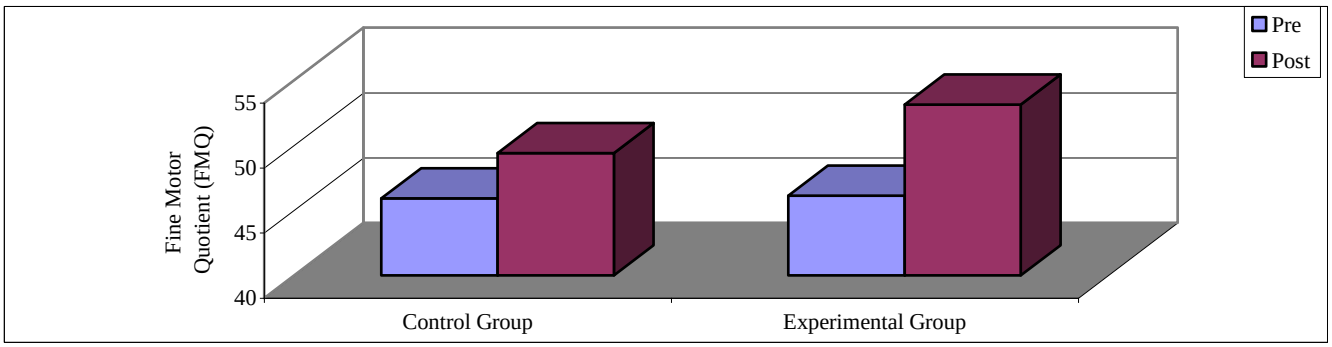

Fig. (3): Pre and post mean values of fine motor quotient (FMQ) both groups.

DISCUSSION

The results of this study showed a significant improvement in both groups in all measuring variables (spasticity and hand function) after 3 months of treatment. However, higher improvement was achieved in the experimental group in all measuring parameters. In agreement with many results of this study that similar to previous studies performed in stroke patients with upper limb spasticity, an immediate therapeutic effect of extracorporeal shock wave therapy in reducing spasticity was found in stroke patients with ankle spasticity. Extracorporeal shock wave therapy can reduce spasticity in stroke patients with lower limb spasticity and prevent complications of spasticity, such as equinovarus deformity [10].

This study only measured the immediate effect of extracorporeal shock wave therapy, but Manganotti and Amelio[10] and Yoo et al.,[26] reported that the therapeutic effect of extracorporeal shock wave therapy on upper limb spasticity could last at least 4 weeks, maximally 12 weeks, and that extracorporeal shock wave therapy had a therapeutic effect on reducing spasticity for a considerable time.

The Extracorporeal shock wave is known to be effective in musculoskeletal diseases for treating pain, inflammation, or injury to a ligament. It produces mechanical effects such as regeneration of degenerated tissue, neovascularization, and resorption of calcium deposit[24,25] and also physiological responses such as changes of epithelial cell permeability, free radical formation, change of cell membrane permeability, nitric oxide (NO) formation, and variable growth factor formation[10,12,21].

The mechanism of shock wave therapy on spastic muscles is unknown. Few studies have investigated the mechanisms of the shock waves, which can induce non-enzymatic[14] and enzymatic nitric oxide (NO) synthesis[25,21,13]. Nitric oxide is involved in neuromuscular junction formation in the peripheral nervous system[3] and in important physiological functions of the CNS, including neurotransmission, memory and synaptic plasticity[8]. NO synthesis has been suggested as an important mechanism to explain the effectiveness of shock waves in the anti-inflammatory treatment of different tendon diseases[25,11,21,13]. However, the reduction in hypertonia in patients with stroke after shock wave therapy is not produced by denervation or lesion of the peripheral nerve, as shown by neurophysiological findings in a previous study[10].

A direct effect of shock waves on fibrosis and on the rheological properties of the chronic hypertonic muscles in cerebral palsy should be considered together with the documented therapeutic effect on bone and tendon diseases[19,16, 18,17,22].

In addition, we might consider possible tixotrophy effects of shock waves on tissues and vessels of the treated muscles[11,12]. The effect of mechanical stimuli of shock waves on the muscle fibers next to the tendon cannot be excluded[8]. Continuous or intermittent tendon pressure can decrease the spinal excitability without long-lasting clinical or neurophysiological effects. Nevertheless, in 12 children group the clinical effects lasted for weeks, excluding a major effect of mechanical vibratory stimulation, which is transitory and short lasting (e.g. some hours)[1].

Another possible mechanism was mechanical vibratory stimulation, which reduces excitability of motor neurons and induces the change of F wave. This rule out that theory because no significant changes of F wave or H-reflex were detected. Considering the clinical antispastic effect observed up to 4 weeks after treatment, mechanical vibratory stimulation, which is transitory and short lasting, could also be excluded as a major effect[8].

In addition, because no signs of denervation were noted in treated muscles, we can exclude any relationship to neuromuscular denervation in the patient cohort treated with shock wave therapy. No changes were observed in either the amplitude or latency of distal motor action potential and late responses, excluding a significant effect of shock wave therapy on peripheral nerves and spinal excitability. On the contrary, the presence of denervation in treated hypertonic muscles and a long-lasting decrease in the amplitude of the motor action potential are

related to the neuromuscular block caused by several types of botulinum neurotoxins[4].

There are several limitations in this study; the mechanism of extracorporeal shock wave for reducing spasticity was not fully evaluated in this study. Further studies are needed to elucidate the mechanism of extracorporeal shock wave for reducing spasticity by comparing the anti-spastic effects. Further studies concerning the correlation between F wave minimal latency and spinal excitability are needed. Similar to results from previous studies conducted for upper limb spasticity[10,26], range of motion of the joint should be measured. Reduced effect of spasticity on other functional abilities such as ambulation or activities of daily living should be assessed. Finally, further studies concerning the most effective level of intensity, number of extracorporeal shock wave treatments, duration of therapeutic effect, and follow up need to be conducted in a larger number of patients.

Conclusion

In conclusion, shock wave therapy appears to be safe, noninvasive, not painful and without complications. These preliminary findings suggest that shock wave therapy may be useful in decreasing flexor tone in children with spasticity of the upper limbs. This therapy could open a new field of research into the non-invasive treatment of spasticity in children. Further studies, with repetitive treatment and with a larger group of patients with cerebral palsy, are therefore necessary.

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الملخص العربي

فعالية الموجات التصادمية علي التشنج ووظائف اليد في الأطفال المصابون بالشلل المخي

أجريت هذه الدراسة لمعرفة تأثير العلاج بالموجات التصادمية علي التشنج ووظائف اليد في الأطفال المصابون بالشلل المخي . وقد أجريت هذه الدراسة على ثلاثين طفلا،ممن تتراوح أعمارهم من خمس إلى سبع سنوات . تم تقسيمهم إلى مجموعتين متساويتين . تلقت مجموعة الدراسة العلاج بالموجات التصادمية علي عضلات المعصم واليد بالإضافة إلى برنامج العلاج الطبيعي لمدة ثلاثة شهور متتالية . بينما تلقت المجموعة الضابطة برنامج العلاج الطبيعي فقط . تم التقييم باستخدام مقياس أشورث المعدل ومقياس بيبودي للتطور الحركي قبل وبعد العلاج . وقد أظهرت النتائج تحسن ذو دلالة إحصائية في درجة التشنج ووظائف اليد بعد العلاج . مما يؤكد أن العلاج بالموجات التصادمية وسيلة فعالة لعلاج الأطفال المصابين بالشلل المخي .

الكلمات الدالة : العلاج بالموجات التصادمية ، التشنج ، وظائف اليد ، الشلل المخي .