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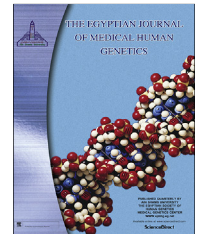

ORIGINAL ARTICLE

Shock wave therapy for spastic plantar flexor muscles in hemiplegic cerebral palsy children

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KEYWORDS

Shock wave therapy;
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Abstract *Background:* The spastic motor type is the most common form of cerebral palsy (CP). Spastic equines foot is the most frequent deformity in ambulated children with CP. Shock wave therapy on spastic muscles of the upper limb in stroke patients provided a significant reduction in muscle tone.

Aim: The present study aimed to investigate the efficiency of shock wave therapy on spastic planter flexor muscles and its relation to the gait in spastic hemiplegic cerebral palsy children.

Methods: Thirty spastic hemiplegic cerebral palsy children from both sexes participated in this study. They were divided randomly into two groups of equal number: Group I (control) included 15 children (6 boys and 9 girls), with mean 5.83 ± 0.34 years, received the therapeutic exercises program only. Group II (study) included 15 children (6 boys and 9 girls), with mean age 5.75 ± 0.51 years, received the same therapeutic exercises program which was given to the control group, in addition to shock wave therapy for 1 week (3 session/week).

Results: Comparing the pre and post treatment mean values of the Hoffman reflex/Motor response (H/M) ratio and gait variables, revealed statistically significant differences in these variables in the study group.

Conclusion: The shock wave therapy is effective in the treatment of hypertonic muscles which help those children to become more independent and participate in everyday activities.

1. Introduction

Cerebral palsy (CP) is a non progressive permanent neurological disorder resulting from a lesion in the undeveloped brain. It has an effect on motor and postural development and grounds sensory disorders and learning disability [1]. CP affects between 1.5 and 2.5 per 1000 live births and is thought to be the most common cause of severe physical disability in childhood [2,3]. The spastic motor type is the most common form of CP [4].

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Spasticity is one of motor disorders that may affect cerebral palsy children. It is characterized by hyperexcitability of the stretch reflex that leads to a velocity dependent enlarge in tonic stretch reflexes with exaggerated tendon jerks [5]. The contraction of the spastic muscle groups will cause skeletal deformities that limit the patient's activity [6]. Spastic equines foot is the most frequent deformity in ambulated children with CP [1].

Therefore, treatment of spasticity plays a significant role in the management of patients with CP. Conservative interventions of spasticity may include passive stretching [7,8], serial plastering [9,10], splints [11,12], pharmacologic treatment [13–16], and botulinum toxin [17–21].

Shock waves are defined as a series of single sonic pulses with high peak pressure (100 MPa), fast pressure rise (< 10 ns) and short duration (10 μs). Different studies and clinical experiments have established the value of shock waves in the treatment of tendinitis calcarea of the shoulder [22,23], epicondylitis [24], plantar fascitis [25], and several tendon diseases, particularly in athletes [26].

A single, active treatment of shock wave therapy on spastic muscles of the upper limb in stroke patients provided a significant reduction in muscle tone. This effect lasted up to 12 weeks after therapy with a particular significant effect on the finger flexors muscle tone [27].

This study aimed to investigate the efficiency of shock wave therapy on spastic planter flexor muscles and its relation to the gait in spastic hemiplegic cerebral palsy children.

2. Subjects and methods

2.1. Subjects

Thirty spastic hemiplegic cerebral palsy children from both sexes participated in this study. They were recruited from the outpatient clinic of the Faculty of Physical Therapy, Cairo University, Abu El Rich Hospital and the Institute of Neuromotor System-Imbaba in the period from January to August 2014. Their age ranged from 5 to 7 years old. They were divided randomly into two groups of equal number: Group I (control) included 15 children (6 boys and 9 girls), with mean 5.83 ± 0.34 years, received the therapeutic exercises program only. Group II (study) included 15 children (6 boys and 9 girls), with mean age 5.75 ± 0.51 years, received the same therapeutic exercises program which was given to the control group, in addition to shock wave therapy for 1 week (3 session/week).

The subjects were selected according to the following criteria:

1. Spasticity grades ranged from 1 to 2 according to modified Ashwarth scale [28,29].
2. IQ level not less than 70% which is the borderline in Wechsler's intelligence classification scale [30] in order to understand and follow orders.
3. All subjects were free from any fixed deformity of both lower limbs.
4. All subjects were able to stand with support.
5. All subjects did not have visual or hearing defects.

The study was approved by an Ethics Committee of the Cairo University. Child's parents were provided with a Volunteer Information Sheet and written consent informing them about the purpose of the study, its benefits and inherent risks and their committee with regard to time and money.

2.2. Instrumentations

2.2.1. For evaluation

2.2.1.1. Modified Ashwarth scale. Computerized electromyography (EMG) apparatus: Neuroscreen plus version 1.59 produced by Toennies, a division of Erich Jaeger GmbH, Germany; 1998 was used to determine H/M ratio.

2.2.1.2. 3D gait analysis system

Data were collected through the use of: Opto-electronic motion analysis system with a force plate unit which was used to measure movements or excursions of the ankle joint.

2.2.2. For treatment

The control group received the therapeutic exercises program only.

The study group received the same therapeutic exercises program which was given to the control group, in addition to shock wave therapy for 1 week (3 sessions/week).

2.2.2.1. Shock wave instrumentation. Extracorporeal shock wave therapy (ESWT) was applied by using the Orthospec (Medispec Ltd, Germantown, MD) portable ESWT device that is approved for distribution and is used in the United States by the FDA. It is connected to electrical main supply 115/230 V, single phase 60/50 Hz and 10/5A was used for creating therapeutic shockwaves. The portable shockwave generator targets the shockwaves to a 35 mm diameter therapy zone that enables shockwaves of sufficient energy to be delivered to the tissues in a single therapeutic session.

2.3. Methods and procedures

H/M ratio and gait measurements were evaluated for each subject before and at the 4th week after shock wave treatment.

2.3.1. For evaluation

2.3.1.1. Spasticity evaluation. Modified Ashworth scale was used [28,29]. The degree of spasticity was evaluated by passive movement for both limbs while the child was completely relaxed, lying supine on a mat with the head in mid position. The test was repeated 3 times and the mean record was taken to refer accurately to the degree of spasticity to select CP children having 1,2 grades.

2.3.1.2. H/M ratio measurement. This measurement was held in a quiet room to avoid any changes in the reflex value. It was obtained from triceps soleus muscles [31].

Setting up the child for recording:

- Sites of stimulating and recording electrodes were cleaned by rubbing the skin using alcohol.
- The procedure was repeated until the skin became slightly red to ensure removing of the degenerated cells and lowering the skin resistance.
- Precautions were taken to avoid irritation especially at the stimulating site.

- Before running the study, the whole procedure was explained to the child's parents, the child's confidence and fined goal friendship were gain.

Electrode placement:

- The child was located in prone position comfortably on the examining table.
- The child' head was kept in mid position to avoid elicitation of any primitive reflex, which may alter the distribution of muscle tone over the child's body during recording.
- The feet were off the table with a pillow placed under the ankle, so that the ankles were placed in a relaxed position.
- Recording was conducted from the soleus muscle as follows: the negative electrode was placed along the mid-dorsal line of the lower leg, 2 cm below the point of separation of the gastrocnemius and secured by adhesive plaster. The other positive electrode was placed distal to the active electrode in a straight line over the tendoachillis and secured by adhesive plaster. The earth electrode was placed between the stimulating and recording electrodes. The stimulating electrode was placed over the tibial nerve just medial to the midpoint of the knee crease in the popliteal fossa.
- The stimulus duration was 1 ms, which stimulates the afferent a nerve fibers and evokes a stable H-reflex.
- Stimulation was at a rate of once every 3 s to avoid blocking response and allow full recording of the reflex response.
- After setting up the child properly on the table and adequately fitting the electrodes in the previously described position, nerve stimulating was conducted by using EMG stimulator.
- The maximal amplitude of H-reflex is often obtained with low intensity. With gradual increase of the stimulus intensity, the M-response amplitude was gradually increased while the H-reflex amplitude was gradually decreased. The H/M ratio was calculated as each value is a mean of three consecutive values of both H-reflex and M-response.

2.3.1.3. 3D gait analysis. Different gait parameters were evaluated [32]. Preparing the system including the following procedures:

A – Setup:

Camera placement:

The three cameras which were used in capturing the patient motion were arranged on the affected side of the 8 m long walkway with three cameras on the affected side. The patient stood midway on the walkway, while the height of the cameras was 1.5 to 2 m.

B – Calibration:

Calibration of the camera system:

The calibration was done as follows:

1- The reference structure was placed in the middle of the measurement volume with the X-axis in the walking direction.
2- Q-Trac calibration was started with the new calibration command.
3- The therapist put the L-shape wand kit on the force platform and standing at either side of the walkway measurement volume. He grasped the T-shape calibration wand in downward direction, vertically moving it in all three directions (X, Y, Z), so that the measurement points were distributed over the entire measurement volume.
4- The wand movement sequence was done as follows:

It was started by having the wand positioned in Z direction and was moved around in the entire measurement volume. Both lower and upper parts of the volume were covered. Then, the entire volume was covered in X direction and finally the same thing was done with the wand directed in the Y direction. It was stressed that the calibration volume fully matched the volume of the motion measured. It took 20–30 s to complete the calibration sequence.

Calibration of the force plate form:

Four reflective markers were placed to each corner of the force plate then they were captured for five seconds. The force plate was captured to synchronize the kinetic data obtained from the force plate with the kinematic data obtained from the cameras.

C – Capture:

Capture or the measurement phase started, which included subject data (name, age, weight and height) and marker setup.

Skin marker setup:

Before starting capturing, each child was asked to take off his/her clothes except the underwear, the reflected dots were fixed to the child's skin by certain sticky material on the specific standard bony landmarks (greater trochanter, suprapatellar, knee joint line, tibial tuberosity, lateral malleolus, toe and heel).

Measurements:

Actual measurements were performed according to the following procedures:

- Before starting the walk on the recording procedure all help was given to the child to get familiar with the walking and gain his self confidence. It was making sense that the child was not distracted by anything in the room, which may change his/her motion pattern.
- Each child was asked to start walking from a position far enough away from the measurement volume to reach a natural continuous walking pattern once he/she entered the measurement volume when he/she heard the alarm.
- Each child walked at self-selected walking speed along the walkway.
- Each child was allowed several practice trials along a walkway at a self-selected pace to feel comfortable with procedure and to strike the force plate without changing his or her gait.
- The child was allowed to continue walking several meters after the measurement volume. Data collection started just before the patient entered the measurement volume and after it, for a few seconds. It was necessary to make sure that relevant data were collected accurately.
- All entire gait cycles were captured within the volume, as the data required for an entire gait cycle were from the first initial contact of one foot to the second toe-off of the other foot.
- The data were then saved to be analyzed later on.

D – Import:

The data processing included two main steps:

- Tracking of the motion data and naming the skin markers each by their position on the bony landmarks.
- Selection of one complete gait cycle and export of this selection to the analysis file were performed.

E – Export:

It is the transfer of the selected gait cycle of the evaluated patient to the TSV file for analysis and obtaining of the desired data.

F – Analysis:

Each subject's data menu was displayed and all relevant data were entered (name, age, sex, weight and height). Markers used for the calculations were then identified. The calculations were initiated with the Run button. When the calculations were completed, the results were displayed showing the calculated global gait parameters. The gait cycle events were indicated as blue and red lines in the lower part of the graphs. There was a time cursor to simplify the interpretation of the graphs.

2.3.2. For treatment

2.3.2.1. The designed therapeutic exercises program used for the control and study groups included the following.

1. Changing position exercises from prone to standing and from supine to standing position which enabled the child to go within the normal sequence of movement up to standing position.
2. Kneeling and half kneeling on the mat to improve balance by fixing of the child's legs in creeping position.
3. Manual standing on the mat, grasping the child around his knees.
4. Manual standing on the mat with step forward and step backward grasping the child around both knees.
5. Standing on one limb on the mat then standing on the other.
6. Balance, equilibrium and protective exercises from standing on the mat by slightly pushing the child forward, backward and laterally to increase standing balance. Also the use of balance board and medical ball is useful to improve equilibrium, protective and righting reactions.
7. Strengthening exercises of the weak muscles like dorsiflexors using manual resistive exercises.
8. Stoop and recovery exercises from standing position.
9. Squatting to standing exercise.
10. Gait training exercise.

2.3.2.2. Shock wave therapy. The protocol of shock wave stimulation was modified from Amelio and Manganotti and Vidal et al. to be 2000 shock of ESWT given as 3 sessions at intervals of one week (700/session), 0.32 mJ/mm^2. Children were treated in sitting position with their affected leg supported by leg rest. The pressure pulses were focused in the hypertonic muscles of the lower limb: shots were used to treat gastrocnemius muscles and soleus muscles mainly in the middle of the belly [33,34].

2.4. Statistical analysis

The mean value and standard deviation were calculated for each variable measured during this study. Paired *t*-tests were calculated for each variable measured during the study. Note that the paired *t*-test provides a hypothesis test of the difference between population means for a pair of random samples. We used level of significance <0.05.

3. Results

3.1. H/M ratio measurements

Comparing the pre and post treatment mean values of H/M ratio in the control group indicated no significant difference as $p > 0.05$. Comparing the pre and post treatment mean values of H/M ratio in the study group revealed a statistically significant difference as $p < 0.05$ (Table 1).

3.2. Gait measurements

3.2.1. Speed, cadence, stride length, single limb support and double limb support

Comparing the pre and post treatment mean values of speed, cadence, stride length, single limb support and double limb support variables in the control group indicated no significant differences as $p > 0.05$. Comparing the pre and post treatment mean values of speed, cadence, stride length, single limb support and double limb support variables in the study group revealed statistically significant differences as $p < 0.05$ (Table 2).

3.2.2. Ankle dorsiflexion in gait cycle

Comparing the pre and post treatment mean values of ankle dorsiflexion at initial contact and at mid stance in the control group indicated no significant difference as $p > 0.05$. Comparing the pre and post treatment mean values of ankle dorsiflexion at initial contact and at mid stance in the study group revealed statistically significant differences as $p < 0.05$ (Table 3). Comparing the pre and post treatment mean values of maximum ankle dorsiflexion in stance phase and at mid swing in the control group indicated no significant difference as $p > 0.05$. Comparing the pre and post treatment mean values of maximum ankle dorsiflexion in stance phase and at mid swing in the study group revealed statistically significant differences as $p < 0.05$ (Table 3).

4. Discussion

This study was conducted to investigate the efficiency of shock wave therapy on spastic planter flexor muscles and its relation to the gait in spastic hemiplegic cerebral palsy children. The age of children included in this study ranged from

Table 1 Pre and post treatment mean values for H/M ratio in control and study groups.

Group	Mean ± SD		MD	*t*-Value	*P* value
	Pre	Post			
Control	4.00 ± 1.20	3.99 ± 1.20	0.01	−1.00	0.33
Study	3.75 ± 1.08	1.95 ± 0.60	1.80	−11.97	0.00*

MD, mean differences; Pre, pretreatment; Post, post treatment.
* Significant.

Table 2 Pre and post treatment mean values for speed, cadence, stride length, single limb support and double limb support in control and study groups.

Item	Group	Mean ± SD		MD	*t*-Value	*P* value
		Pre	Post			
SP	Control	0.68 ± 0.02	0.68 ± 0.02	0.00	1.47	0.16
	Study	0.67 ± 0.04	0.90 ± 0.06	0.23	13.35	0.00*
CA	Control	119.60 ± 2.75	119.40 ± 2.77	−0.20	−1.87	0.08
	Study	118.20 ± 2.33	117 ± 2.20	−1.20	−6.00	0.00*
SL	Control	0.72 ± 0.45	0.73 ± 0.44	0.00	0.56	0.58
	Study	0.70 ± 0.02	0.96 ± 0.05	0.25	21.27	0.00*
SLS	Control	0.36 ± 0.13	0.36 ± 0.14	0.00	1.87	0.82
	Study	0.36 ± 0.12	0.40 ± 0.20	0.03	12.67	0.00*
DLS	Control	0.27 ± 0.04	0.27 ± 0.04	−0.001	−1.47	0.16
	Study	0.26 ± 0.04	0.21 ± 0.04	−0.049	−16.43	0.00*

MD, mean differences; Pre, pretreatment; Post, post treatment; SP, speed; CA, cadence; SL, stride length; SLS, single limb support; DSL, double limb support.
* Significant.

Table 3 Ankle dorsiflexion in gait cycle.

Item	Group	Mean ± SD		MD	*t*-Value	*P* value
		Pre	Post			
ADTC	Control	−3.53 ± 1.51	−3.33 ± 1.72	0.20	1.87	0.82
	Study	−3.87 ± 1.85	7.20 ± 1.78	11.07	14.58	0.00*
ADMS	Control	5.53 ± 1.81	5.67 ± 2.02	0.13	1.67	0.16
	Study	5.13 ± 2.20	12.13 ± 2.42	7.00	27.11	0.00*
MADST	Control	10.80 ± 2.08	11.00 ± 2.00	0.20	1.87	0.82
	Study	9.53 ± 1.81	16.20 ± 1.82	6.67	20.92	0.00*
MADSW	Control	−2.47 ± 3.11	−2.27 ± 3.24	0.20	1.87	0.82
	Study	−3.93 ± 3.10	7.00 ± 1.36	10.93	18.30	0.00*

MD, mean differences; Pre, pretreatment; Post, post treatment; ADTC, ankle dorsiflexion at initial contact; ADMS, ankle dorsiflexion at mid stance; MADST, maximum ankle dorsiflexion in stance phase; MADSW, maximum ankle dorsiflexion at midswing.
* Significant.

five to seven years old. Both sexes were involved in this study. The results of this study showed a significant reduction in muscle tone for the study group which come in agreement with Vidal et al., who stated that there was a significant reduction in muscle tone in a spastic cerebral palsy patient treated with rESWT and this reduction lasted up to 2 months after treatment [34]. It also comes in agreement with Amelio and Manganotti who reported that the use of a single active treatment of shock wave therapy for the spastic muscles of the children with cerebral palsy produced a significant reduction in muscle tone [27,33]. The results of this study also showed that there was a significant improvement in speed, cadence, stride length, single and double limb supports and ankle dorsiflexion during gait cycle. These results come in agreement with Amelio and Manganotti who suggested that reduction of the spastic plantar flexor muscles increases the plantar surface area on the affected side in spastic cerebral palsy children [33]. Manganotti and Amelio noted that there was a significant improvement in passive range of motion of the wrist extensor in patients affected by stroke who were treated using a single, active treatment of shock wave therapy [27]. Little information is available about the use of shock wave therapy on spastic muscle. Improvements detected in the study group using shock wave therapy may be attributed to non-enzymatic [35] and enzymatic nitric oxide (NO) synthesis [36–38]. NO is involved in neuromuscular junction formation in the peripheral nervous system [39] and in important physiological functions of the CNS, including neurotransmission, memory and synaptic plasticity [40]. 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 [36–38]. A direct effect of shock waves on fibrosis and on the rheological properties of the chronic hypertonic muscles in CP should be considered together with the documented therapeutic effect on bone and tendon diseases [33]. In addition, we might consider possible thixotropy effects of shock waves on tissues and vessels of the treated muscles [36,37]. The effect of mechanical stimuli of shock waves on the muscle fibers next to the tendon cannot be excluded [41]. Continuous or intermittent tendon pressure can decrease the spinal excitability.

5. Conclusion

It may be concluded that the shock wave therapy is effective in the treatment of hypertonic muscles which help those children to become more independent and participate in everyday activities. More researches with larger sample sizes are recommended.

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No benefits or funds were received in support of this study. None of the authors has received or will receive benefits for personal or professional use from a commercial party related directly or indirectly to the subject of this article.

Conflict of interest

Authors have not declared any conflict of interest.

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