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Calf Muscle Strength and Standing Efficiency in Children with Spastic Diplegia

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ABSTRACT

The purpose of this study was to evaluate the effect of calf muscle strengthening on standing function and posture in spastic diplegic cerebral palsied children. Thirty spastic diplegic children with age ranged from 2-4 years participated in this study. They were assigned randomly into two groups of equal numbers, control (A) and study (B). Each patient of the two groups was evaluated before and after treatment by using standing dimension of Gross Motor Function Measure-88, AutoCad 2007 software program for measuring knee and ankle joints angles in sagittal plan during standing and ultrasonography for measuring calf muscle thickness before and after three successive months of application of the treatment programs. The control group received a selected physical therapy program for one hour per session. The study group received the same selected physical therapy program given to the control group for one hour in addition to strengthening exercises and electrical stimulation program for calf muscles of both lower limbs. The program of treatment was conducted at 3 times/week basis for three successive months. The pre-treatment results revealed no significant difference in all measured variables between the two groups. While significant difference in all measured variables between the two groups were recorded after the treatment period in favor of the study group. These results show the importance of strengthening the calf muscles in spastic diplegic children.

Key words: Calf muscle, strengthening exercises, spastic diplegia, standing position and electrical stimulation

INTRODUCTION

Cerebral Palsy (CP) is the most common chronic disability of childhood today (Berker and Yalcin, 2010). Cerebral palsy describes a group of permanent disorders of the development of movement and posture, causing activity limitations that are attributed to non-progressive disturbances that occurred in the developing fetal or infant brain (Campbell *et al.*, 2012).

The classification of the subtypes of cerebral palsy is based upon clinical determinations of movement disorder that may change presentation as the child grows and develops. This movement disorder is topographically classified by the number of limbs impaired into hemiplegia, diplegia and quadriplegia and by symptoms of impairment cerebral palsy is classified into spastic, dyskinetic and a rare ataxic type (Levitt, 2010).

When a person is standing, the ankle joint is less stable than the hip and knee joints and the line of gravity falls between the two limbs just anterior to the axis of rotation of the ankle joints. Consequently, a tendency to fall forward (forward sway) must be countered periodically by bilateral contraction of the calf muscles (Nordin and Frankel, 2001; Moore *et al.*, 2010).

In addition, calf muscles are relatively weaker in spastic diplegic children than in normal children (Ross and Engsborg, 2002). Calf muscles may benefit from strength training as they exhibit poor submaximal control and weakness in children with CP (Bandholm *et al.*, 2009).

Techniques such as neuromuscular electrical stimulation (NMES) may be helpful for strengthening muscles that cannot be sufficiently recruited with voluntary effort in CP children (Stackhouse *et al.*, 2005). The exact mechanism by which NMES might improve motor function in children with cerebral palsy is unclear. Study on mechanism of action of NMES indicate that it may increase muscle strength by increasing the cross-sectional muscle area (Scheker *et al.*, 1999).

The purpose of this study was to investigate the effect of strengthening the calf muscles on standing efficiency in children with spastic diplegia.

MATERIALS AND METHODS

Thirty children with spastic diplegia of both sexes were recruited from the Out-Patient Clinic of the Faculty of Physical Therapy, Cairo University and participated in this study. Agreement of the Ethical Committee of the Faculty of Physical Therapy was obtained before the beginning of the study. Children were selected according to the following criteria:

Inclusion criteria:

- Children age ranged between 2 and 4 years
- They were classified at level III by Gross Motor Function Classification System; (they can stand with hand support but can't stand with hands free)
- Children with mild and moderate spasticity (i.e., grade 1 and 2, according to Modified Ashworth Scale (Bohannon and Smith, 1987))
- Parent's consent

Exclusion criteria:

- Children with severe spasticity (i.e., grade 3 and 4, according to Modified Ashworth Scale)
- Fixed deformities
- Uncontrolled seizures
- Surgery or Botox injection during last six months before study
- Children receiving another physical therapy program during the participation in this study

Design: All children were divided randomly into two groups of equal number (15 patients each) using closed envelopes procedures:

- Control group (A) received a selected physical therapy program

- Study group (B) received the same selected physical therapy program in addition to manual and mechanical strengthening exercises and electrical stimulation program for calf muscles of both lower limbs
- Both groups received 3 sessions/week for 3 successive months

Instrumentation and tools for evaluation:

- Gross motor function measure-88 was used for measuring standing dimension score
- AutoCAD 2007 (software program) was used for kinematic analysis of knee and ankle joints angles in sagittal plan during standing
- Ultrasonography device, GE-Healthcare ultrasound device was used to measure total calf muscle thickness with a high frequency, high resolution probe (up to 12-15 MHz)

Instrumentation and tools for treatment:

- Electrical stimulation device, AMREX® (MS324A, USA) with low volt alternating current stimulator was used to strengthen the calf muscles of both sides

Procedures:

- Evaluation for both groups (group A (control) and group B (study) was conducted before and after three successive months of treatment
- Only standing dimension score of GMFM-88 was measured (pre-and post-treatment)
- By using AutoCAD 2007 (software program), knee and ankle joints angles in sagittal plan during standing were measured pre and post-treatment. Full view of the child without zooming was taken by a digital camera while the child was standing holding on to a metal bar. The camera was mounted on a stable tripod and the optical axis of the camera was aligned perpendicular to the plane of the child. Knee joint angle was determined by the posterior angle formed by the intersection between 2 lines. The first line passed from the greater trochanter to knee joint axis and the second line passed from the knee joint axis to lateral malleolus. Ankle joint angle was determined by the anterior angle formed by the intersection between 2 lines. The first line passed from the knee joint axis to lateral malleolus and the second line passed from the inferior tip of calcaneus to the base of the fifth metatarsal bone
- Ultrasonography, was used to measure transverse thickness of soleus, medial and lateral gastrocnemius at the level between the upper and second fourths of the lower leg while the child was in prone position and the feet were rested on the plinth. The transducer was applied perpendicular to the skin without excessive pressure. Total calf muscle thickness was calculated by the summation of the transverse thickness of the three muscles. The assessor was blinded from subject's group

Treatment

Group A (control): The selected physical therapy program was in the form of: Standing holding on exercises, squatting to stand exercises, pull to stand from sitting position, pull to sit from supine



Fig. 1: Manual calf muscle strengthening

and prone positions, weight-shifting exercises, range of motion exercises for hip flexors and adductors and knee flexors, balance exercises, vestibular exercises and gait training. The treatment session duration was 1 h.

Group B (study): Children received the same selected physical therapy program of group A in addition to:

- Manual and mechanical strengthening of calf muscles: 10 repetitions, 3 sets/session with 1 min rest between sets (Fig. 1)
- Neuromuscular electrical stimulation (NMES) program for calf muscles with the following parameters:
 - Alternating biphasic waveform current
 - Frequency of 30-80 Hz
 - Intensity of maximal comfortable muscle contraction, increased gradually during session
 - On:Off ratio of 5 sec on and 5 sec off
 - Surge mode current with a gradual ramp to peak intensity
 - Placement of electrodes: One electrode on the middle of soleus muscle and the other electrode covering both heads of gastrocnemius with the distance between electrodes greater than or equal to the size of one of them
 - Electrical stimulation duration was 15 min

Statistical analysis: Statistical analysis of the data was performed using SPSS software for medical statistics. The data were collected before and after three months of training for both groups. The significance level was set at $p < 0.05$.

- **Descriptive statistics:** The mean and standard deviation of each group were calculated for each variable pre and post treatment
- **Inferential statistics:** Comparing mean values of pre and post treatment within the same group was done by paired t-test while comparing mean values of each variable between the two groups was done by unpaired t-test

RESULTS

Descriptive data of the control and study groups: As shown in Table 1, comparing mean values of age and body mass index for the two groups revealed non-significant difference ($p>0.05$).

Standing dimension of GMFM-88: Table 2 demonstrates the pre and post treatment values of all measured variables for both groups. Comparing the pre and post treatment values of standing dimension for both groups, there was significant improvement in both groups with the percentage of improvement in the study group was greater than the percentage of improvement in the control group.

Table 1: Descriptive data of both groups

Item	Groups (Mean±SD)		p-value	Significance
	A	B		
Age (months)	34.13±5.54	33.87±6.78	0.91	NS
Body mass index (kg m^{-2})	14.98±1.61	15.09±1.64	0.85	NS

SD: Standard deviation, NS: Non significant

Table 2: Pre and post treatment values of all measured variables for both groups

Variables	Groups (Mean±SD)		p-value	Significance
	A	B		
Standing dimension (%)				
Pre	25.27±9.360	25.31±14.46	0.99	NS
Post	28.80±8.790	40.11±15.45	0.02	S
Right knee angle (degrees)				
Pre	167.79±17.57	166.91±15.06	0.88	NS
Post	165.33±18.56	177.05±9.240	0.04	S
Left knee angle (degrees)				
Pre	166.81±17.68	165.46±15.45	0.83	NS
Post	165.09±14.30	176.48±10.90	0.02	S
Right ankle angle (degrees)				
Pre	76.98±10.18	77.75±6.890	0.81	NS
Post	78.39±9.360	89.81±7.430	0.001	S
Left ankle angle (degrees)				
Pre	76.73±7.350	78.37±5.980	0.51	NS
Post	79.10±7.670	88.13±5.150	0.001	S
Right calf thickness (cm)				
Pre	2.47±0.180	2.48±0.240	0.87	NS
Post	2.41±0.240	2.68±0.350	0.02	S
Left calf thickness (cm)				
Pre	2.46±0.210	2.46±0.320	0.98	NS
Post	2.41±0.130	2.63±0.370	0.04	S

Ns: Non significant, S: Significant

Kinematic analysis: Comparing the pre and post treatment values of knee and ankle angles for both groups, there was a significant improvement only in study group.

Calf muscle thickness: Comparing the pre and post treatment values of calf muscle thickness for both groups, significant improvement was recorded only in study group.

DISCUSSION

This study focused on one of the major gross motor skills a child should acquire; proper independent standing. As Styer-Acevedo (2008) reported that the ability to stand is a major concern of parents of diplegic cerebral palsied children. He added that improving this ability is often considered to be the primary focus of the most therapeutic intervention.

As indicated from the results of descriptive data of the two groups control and study (A and B), subjects in both groups were homogenous concerning age and BMI.

The pre-treatment results revealed non significant difference in all measuring variables between the two groups which confirm the homogeneity of the sample in the control and study groups before starting the treatment program.

After the termination of the suggested treatment programs, the results of the current study showed significant difference ($p < 0.05$) between the mean values of post treatment results of variables recorded in the control and study groups in the favour of study group which clearly demonstrate the positive effect of calf muscle strengthening on the standing efficiency in the spastic diplegic cerebral palsied children.

In the present study, the significant post-treatment results obtained from measurement of standing dimension of GMFM-88 of the study group might be attributed to improvement of calf muscles strength which is the main antigravity muscle during static standing (Moore *et al.*, 2010). Winter (1991) showed that 50% of the moment production to maintain upright standing posture is supplied by the calf muscle activation.

The soleus typically is thought of as an ankle plantar flexor. However, when the foot is in a plantigrade position, the soleus is active and works to restrain the forward movement of the tibia. Therefore, it functions as a knee extensor. This is known as the plantar flexion/knee-extension couple. Unfortunately, the insufficient plantar flexion/knee-extension couple is common and contributes to crouch posture in CP children (Hsu *et al.*, 2008). In addition, plantar flexor dysfunction leads to both stance phase (supportive) and swing phase (propulsive) deficiencies during gait. Therefore, increasing calf strength can improve crouch posture of diplegic child resulting in reduced energy expenditure during standing and walking.

Such results supported the findings of Chan *et al.* (2004) who studied the effect of NMES on the triceps surae muscle in improving the gait and function of children with cerebral palsy aged 4-11 years. In addition, improvement of knee and ankle joints ROM may be due to the direct effect of NMES on tight and spastic calf muscles (Maenpaa *et al.*, 2004; Wiart *et al.*, 2008).

Also the significant improvement in crouch posture recorded in the study group came in agreement with Huh *et al.* (2010) who found that soleus weakness is a major risk factor for the development of crouch gait in CP children.

In the present study, muscle thickness was selected as an alternative method of quantitative muscle evaluation for children with CP for whom direct measurement of muscle strength was difficult (Ohata *et al.*, 2006).

Moreau *et al.* (2010) stated that ultrasound measures of muscle thickness adjusted for age and GMFCS level were highly predictive of maximal torque and have the potential to serve as surrogate

measures of voluntary strength (force-generating capacity) in children and adolescents with and without CP. In addition, they proposed an alternative measure of strength using 2-dimensional real-time ultrasound imaging that can be used when strength testing is not feasible in children with cerebral palsy.

This came in contradiction with O'Sullivan *et al.* (2009), who found that the correlation between muscle size (by tape and ultrasound) and the concentric isokinetic quadriceps and hamstrings strength was only weak to moderate. His study was limited by smaller sample size formed of normal persons.

This study showed increased calf muscle thickness in the study group which coincided with the results of McNee *et al.* (2009) who found an increase in muscle volume after plantar flexor strength training in children with spastic cerebral palsy.

It is worth mentioning that there was no any adverse effects such as muscle fibrosis, inspected by ultrasonography at the end of this study at the calf muscles in the study group, at which NMES was used.

Choosing 3 months period for this study may be explained by Kisner and Colby (2012) who stated that strength gains observed early in a resistance training program (after 2 to 3 weeks) are the result of neural adaptation. For significant changes to occur in muscle such as hypertrophy or increased vascularization at least 6 to 12 weeks of resistance training is required.

A very recent meta-analysis supported our choice of session duration (1 h) and frequency of sessions per week (3 sessions/week). It concluded that the optimal strengthening exercise for CP children consisted of 40 to 50 min sessions performed 3 times per week (Park and Kim, 2014).

There is now a growing body of evidence which demonstrates that children with cerebral palsy can benefit from strengthening exercises and NMES. Choosing the target muscles for those techniques is a very important factor influencing the result of the treatment (Park and Kim, 2014; Novak *et al.*, 2013).

In the present study, the significant post-treatment results obtained from measurement of all variables of the study group might be attributed to improvement of calf muscle strength, increased stability of knee and ankle joints, improved elasticity of calf muscle, decreased energy expenditure during standing, improved balance, improved plantar flexion/knee-extension couple, increased sensory awareness of isolated calf movement, improved foot alignment and decreased reliance on proximal muscles instead of distal muscles.

CONCLUSION

On basis of the present study supported by the relevant literature, it can be concluded that calf muscle strengthening using active exercises and NMES can be effective in improving standing function and posture in children with spastic diplegic CP.

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