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Motor control and standing function following strength training in spastic diplegia children.

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ABSTRACT

Background and purpose: Poor selective motor control is a prominent characteristic of children with cerebral palsy. The aim of this work was to study the effect of strength training for lower limbs muscles on motor control and standing function in children with diplegia. **Subjects and methods***:* Forty spastic diplegia children of both sexes aged between 4 and 6 years (Gross Motor Function Classification System Levels IV and V) participated in this study. They were classified randomly into two groups of equal number, (control and study). Both groups received especially designed physical therapy program, and the study group received strengthening training program using the UEU for three successive months. The variables that represented motor control included time to reach peak force and the agonist /antagonist ratio for knee joint flexors/extensors muscles in both lower limbs were assessed using Biodex Isokinetic System. Standing function was assessed by Gross Motor Function Measure Scale. **Results:** The results revealed no significant difference when comparing the pre-treatment mean values of the two groups, while significant improvement was observed in all the measuring variables of the two groups (P<0.0001) when comparing pre and post treatment mean values. Significant difference was observed when comparing the post treatment results of the two groups in favor of the study group. **Conclusion:** Strength training using UEU is a beneficial modality that can be used to improve motor control and standing function in cerebral palsy children.

Key Words: Cerebral Palsy, Diplegia, Isokinetic Testing, Motor Control, Universal Exercise Unit, Gross Motor Function Measure.

• Introduction

Children with cerebral palsy (CP) have neurodevelopment disorders, such as spasticity, contracture, reduced coordination, selective voluntary motor control, and muscle weakness [14]. Among these, muscle weakness is a major motor problem for children with cerebral palsy [9, 30]. The presence of weakness in children with spastic diplegia is now well documented, and the most functional individuals demonstrating substantial generalized muscle weakness [3, 44].

Selective voluntary motor control is defined as the performance of isolated movement while performing a functional task as walking, and the ability to activate muscles independently in response to voluntary motor requirements in amounts appropriate for recruitment and activation of muscles [33]. Compared with normal children, cerebral palsy children have various muscle recruitment patterns and magnitudes [39], and these differences can affect voluntary muscle recruitment leading to impairments in motor ability [18]. It was found that children with spastic diplegia use movement patterns described in normal children but with intra and inter-individual variability. This characterizes the limited repertoire of movement in patients with spastic diplegia and therefore contribute to a better understanding of motor control[5]. In prepubescent youth who are developing typically, changes following resistance training appear to have more effect on neural factors as improvements in motor skills, increases in motor unit recruitment and firing rate, and changes in coordination [23, 35].

Muscle strength and resistance training have been widely used as a therapeutic intervention for increasing muscle strength and functional improvement [7, 10, 21].In the past, muscle strength training for children with CP was not considered viable because it required much effort by the children and led to increase in muscle spasticity [2]. However, some studies have reported that children with spastic CP do not show an increase in muscle spasticity after performing muscle strength training [12, 29]. The universal exercise unit (UEU) is used to assist children in functional activities along with strengthening exercises. The UEU is a three dimensional metal cage with the addition of pulleys, cables, and weights can be used for different rehabilitation techniques. It refers to the unit as the spider cage because of the bungees used. The children are hooked in the "spider cage" with a belt around their waist that is attached to the cage using bungee cords. Just enough assistance is given using the bungee cords to allow the child the security and balance needed to practice activities on their own independently [19].

Isokinetic dynamometers provide accommodating resistance during dynamic exercises and testing of the extremities and trunk. The equipment supplies resistance proportional to the force generated by the person using the machine. The preset rate cannot be exceeded no matter how vigorously the person pushes against the force arm. Therefore the muscle contracts to its fullest capacity at all points in the range of motion [32]. The isokinetic dynamometer has been considered the gold-standard evaluation because it allows a quantitative evaluation of muscle function, throughout variables such as torque, power, and endurance [1, 19].

The Gross motor function measure (GMFM) is a standardized, criterion-referenced test designed to assess changes in gross motor function in children with CP [31]. The GMFM-88 has been shown to have high levels of validity, reliability, and responsiveness in evaluations of motor function and intervention effects in children with CP [31]. It is a well system established to classify gross motor function, providing an easy-to-understand tool for clinicians and researchers that have a high level of inter-rater reliability and which have been used extensively to describe study populations as motor function in children with CP [20, 26].

This study was designed to determine the effect of strengthening lower limb muscles using the UEU on motor control and standing function in children with spastic diplegia.

- **METHODS**
- I-*Subjects*

Forty children from both sexes with spastic diplegia and age ranged from 4 to 6 years old participated in this study. Inclusion criteria were that they were grade 1 of spasticity according to modified Ashworth's scale, Gross Motor Function Classification System Levels D, able to understand orders, no fixed deformities in lower limbs, or visual and auditory problems. They were selected from the outpatient clinic, Faculty of Physical Therapy, Cairo University. Participants were randomly assigned into two groups of equal number (control and study groups), by asking each child to pick up an index card out of a box which contains 40 cards (20 cards for each group) to determine which group he/she would be in.

Evaluation was conducted for each child of the two groups by measuring time to peak force and agonist/antagonist ratio for knee joint flexors/extensors muscles in both lower limbs by the Biodex System dynamometer (Shirley, NY) .The standing function was assessed by the GMFM-

88 pre and post three successive months of conducting the program. Both groups received especially designed physical therapy program. Additionally, the study group received strength training by UEU.

II- Materials and Instrumentation:

A- For evaluation

1- *Biodex System Dynamometer*

It is an isokinetic dynamometer, which consists of dynamometer motor that can shift and rotate in order to fit the position of the trained joint. Positioning chair with 360 degrees of rotation motorized seat height adjustment and superior stabilization. Number of shaft that is specially designed to adapt to each trained joint and a computer used to monitor and record tested muscle performance.

2- *Gross motor function measure*

The GMFM-88 was used to evaluate task of standing. The GMFM is a standardized, criterion-referenced test designed to assess changes in gross motor function in children with CP [31]. Dimension D (13 items), which measures motor activities for CP children while standing on. It was chosen as the outcome measures in this study.

B-For treatment

1- Mats, wedges, medical balls, rolls, and tilting boards of different sizes and shapes were used to conduct the selected program.

2- Universal exercise unit: formed of cage, table, weights, pulley systems and straps for child fixation.

III-Procedures:

A- For evaluation

1- Biodex system dynamometer

All parents had been informed about study procedures and objectives for their children with the absence of any risk. After signing a written consent form, instructions about evaluative procedures were explained for each child before the testing session to make sure that all children understood the steps of evaluation and are familiar with the device. All of the children were familiarized with the Biodex test in a similar manner. Children were allowed to practice the actual movement during three submaximal repetitions without load as warm-up. More repetitions were not allowed to prevent the possible onset of fatigue. Personal data was provided including name, age, weight, address and phone number.

According to a pilot study and Damiano et al., 2010 [4] the following items were detected:

- Starting position: 45 degrees flexion for both hips and knees of both lower limbs.
- Range of motion: from 45 degrees flexion to 0-degree extension.
- Pushing velocity: 9.17 m/sec.
- Movement repetitions: 5 repetitions.

Each child was seated in semi reclined position and the trunk was fixed by straps and he or she was asked to move or push the handle. [13].

The variables measured included: Time to peak force, which is the average measure of the time from the start of the muscular contraction to the peak torque point of each repetition. The agonist/antagonist ratio for knee joint flexors/extensors muscles is calculated as the ratio between the peak values of the concentric torque of the flexor muscles, and the concentric peak torque of the extensor of the knee [32].

2- *Gross motor function measure system:*

Dimension D that represented the standing function was measured. The items are scored from 0 to 3. Values of 0= cannot do; 1=initiates (< 10% of the task); 2= partially completes (10 to < 100% of the task); 3= task completion [31]. All items were summarized and expressed as a value of total points for standing dimension of the GMFM-88. The GMFM-88 total score is calculated as the mean score of all 13 items of the D-dimension. Tests for all items of the GMFM-88 were administered in a pediatric physical therapy room that was comfortable and familiar to the children. The tests were conducted in the order given in the GMFM manual by two therapists. During the tests, the children were barefoot and used no assistive devices. It took 10 to 15 minutes to record each child's standing movements. The scoring of the items was performed and recording in the testing session.

For treatment

Treatment protocol:

The especially designed program that was conducted for both groups included:

1- Stretching exercises: for calf muscles, hamstrings, hip adductors and hip flexors.
2- Exercises to facilitate postural control: including stoop and recovery, and squatting.
3- Balance and equilibrium training was carried from different positions (quadruped, kneeling, half kneeling and standing) on tilting board.
4- Facilitation of standing from different positions.

Strengthening exercises for both lower limbs that was conducted for the study group only using the UEU:

Each child was in supine lying position on the table inside the spider cage, while he/she was fixed with straps on the chest, pelvis and on the non-involved limb while the other lower limb was free to perform exercise. The child was asked to push his/her lower limb against weight, which was determined as follows: selected weight was determined by the physical therapist depending on the ability of the child completing two sets of 10 repetitions. The training load was adjusted such that each participant could complete only between 8 and 10 repetitions of the exercise with “good form” before fatigue set in. The intensity was explained such that the children completed 3 sets of between 8 and 10 repetitions (total of 24–30 repetitions) for the exercise according to Dodd et al.,(2003) and Scholtes et al.,(2008) [7,34].

RESULTS

The raw data were analyzed using the SPSS program to determine the mean± standard deviation for each measuring variables of the two groups before and after three successive months of treatment. Parametric tests included in this study were independent t-test used to compare post results of the two groups and paired t-test to compare pre and post results in each group regarding time to peak force and agonist/antagonist ratio measures. Mann-Whitney test was used to compare GMMFS between groups.

The obtained results in this study revealed no significant differences when comparing the pre-treatment mean values of the two groups in the all measured variables.

General characteristics for the subjects:

Control group: included twenty spastic diplegia children (12 boys and 8 girls) with age ranged chronologically from 4 to 6 years mean value (5.37 ± 0.87) and weight ranged from 14.6 to 19.2 kg with mean value (16.63 ± 2.89) .

Study group: included twenty spastic diplegia children (11 boys and 9 girls) with age ranged chronologically from 4 to 6 years mean value (5.53 ± 0.82) and weight ranged from 14.6 to 19.4 kg with mean value (16.45 ± 2.63) .

1- *Time to peak force:*

There was a significant reduction in the time to peak force (millisecond) for the knee extensor muscle both lower limbs in the two groups when comparing pre and post mean values ±SD in the two groups(P < 0.0001) as shown in table 1. Significant improvement was also observed when comparing the post-treatment mean values of the two groups in favor of the study group as shown in table 2 and figure 1, (P< 0.0001).

Table 1. Pre and post-treatment mean values of the time to peak force for knee extensor muscle both lower limbs in the study and control group.

Control group (n=20)				Study group (n=20)				Time to peak force (milliseconds)
Right L.L		Left L.L		Right L.L		Left L.L		
Pre	Post	Pre	Post	Pre	Post	Pre	Post	
112.85	126.95	107.85	126.05	70.10	128.60	64.35	127.05	X'
13.02	12.03	13.28	10.52	20.40	12.30	19.70	12.67	SD
9.58		11.33		17.40		18.98		t-value
.0001		.0001		.0001		.0001		P-value
Significant		Significant		Significant		Significant		Level of significance

Table 2. Post-treatment mean values of the time to peak force for knee extensors muscle both lower limbs in the study and control groups.

Left Lower Limb		Right Lower Limb		Time to peak force
Control group	Study group	Control group	Study group	

112.85	70.10	107.85	64.35	X'
13.02	20.40	13.28	19.70	SD
-7.98		- 8.18		t- value
.0001		.0001		P-value
Significant		Significant		Level of significance

Figure 1. Post-treatment mean values of the time to peak force for the study and control group for both lower limbs.

2- Agonist/antagonist ratio:

There was a significant reduction in the agonist/antagonist ratio (%) for knee flexors/ extensors muscles when comparing pre and post mean ranks in the two groups (P < 0.0001) as shown in table (2). Significant improvement was also observed when comparing the post-treatment mean ranks of the agonist/antagonist ratio of the two groups in favor of the study group as shown in table (4) and figure (2).

Table 3. Pre and post-treatment mean values of the agonist/antagonist ratio for knee flexors/extensors muscles in the study and control groups

Control group (n=20)			Study group (n=20)		Agonist/ Antagonist ratio
Left L.L	Right L.L		Left L.L	Right L.L	
Pre Post	Pre Post		Pre Post	Pre Post	
	10.5	10.5	10.5	10.5	Mean rank
	-3.92	- 3.92	-3.92	-3.92	z-value
	.000	.000	.000	.000	P-value
	Significant	Significant	Significant	Significant	Level of significance

Table 4. Post-treatment mean values of the agonist/antagonist ratio for knee flexors/extensors muscles in the study and control groups

Left Lower Limb		Right Lower Limb		Agonist/antagonist Ratio %
Control group	Study group	Control group	Study group	

29.90	11.10	29.50	11.50	Mean rank
-5.08		- 5.11		Z- value
.000		.000		P-value
Significant		significant		Level of significance

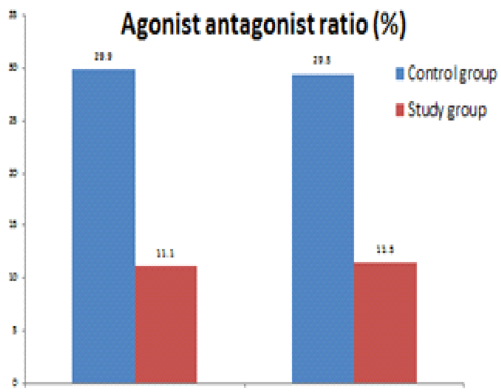

Figure 2. Post-treatment mean values of the agonist/antagonist ratio for the study and control groups both lower limbs.

3- Gross Motor Function Measure Scale:

There was a significant increase in the scores of standing when comparing pre and post mean values ±SD in the two groups ($P < 0.0001$) as shown in table (3). Significant improvement was also observed when comparing the post-treatment mean values of the standing of the two groups in favor of the study group as shown in figure (3).

Table 3. Pre and post-treatment mean values of GMFM for the study and the control group.

Control Group		Study Group		
Post	Pre	Post	Pre	
34.00	23.56	41.50	23.80	X
2.69	1.31	1.43	1.39	±SD
3.942		3.941		z-value
.000		.000		P-value
Significant		Significant		Level of significance

Figure 3: Post-treatment mean values of GMFM Scale for the study and the control group

DISCUSSION

Cerebral palsy patients present with impairments in body function such as spasticity, low muscle strength, and selective motor control. These impairments may limit the performance of activities and participation in daily life. Improving and optimizing activities and participation are important treatment goals for therapeutic interventions [34]. The neuromuscular adaptations following resistance training have not been studied to a great extent in children and adolescents with CP. Given that the primary pathology in CP involves the motor system, it is possible that the adaptability of neural factors following resistance training is reduced in this group, as has been suggested by some authors[35] who showed decreased voluntary activation of muscle in children with CP compared with that of their peers who were developing typically. It has been shown that low muscle strength, and not spasticity causes the greatest limitations in motor function in children with CP [30] and this has shifted the focus from spasticity management towards strength training for these children [34]. To be successful, strength training must be individualized, and should involve a progressive increase in intensity, thereby stimulating strength gains that are greater than those associated with normal growth and development [15].

Cerebral palsy CP is the most prevalent physical disability originating in childhood, with the largest proportion of this patient population having spastic diplegia, characterized by involvement primarily in the lower extremities [17]. The objective of this study was to reveal the effect of strengthening of both lower limbs in improving motor control and its impact on standing function in spastic diplegia children. A total of 40 children participated voluntarily were divided into control and study groups. Knee extensor strength correlated directly with the standing function. Primary weakness and secondary disuse of this muscle group, coupled with abnormal movement patterns, may lead to muscle atrophy and rearrangement of the internal muscle architecture, thus adversely affecting function [25].

A protocol was developed to strength lower limb muscles, based on the current guidelines for progressive resistance exercise strength training in healthy children[11], and on strength training for CP [37, 42].

The UEU, also known as the "monkey cage" and the "spider cage." The monkey cage uses the UEU with a system of pulleys and weights to isolate muscle groups and allow for strengthening without compensating with other muscle groups. The spider cage uses the UEU with a system of eight elastic/bungee cords attached to a waist belt. This system allows the patient to experience more independent movements, weight shifting, and assisted movements. The therapist guides the child through exercises to strength muscles and allows the patient to experience movements [24].

Selection of the age of participated children in this study aiming to understand and follow verbal commands and instructions included in both tests and training. Because motor functioning is related to age and severity of CP these characteristics should be taken into account when defining the optimal group of children for resistance training [44]. This coincided with a study, which revealed that children from 3 to 6 years begin to use somatosensory information appropriately [43].

Choosing Biodex Isokinetic Dynamometer for muscle strengthening evaluation was accepted by many authors [4, 44], who stated that the use of isokinetic testing as a mean of measuring dynamic muscle strength has increased considerably as a standard method for strength measurement throughout a range of speeds requiring isolated joint movement which is problematic in CP children due to impaired selective motor control [13]. This was managed in the present study by strength assessment of full limb extension and flexion across a selected comfortable speed according to the pilot study.

Individuals with muscle weakness usually do not have enough strength to move the lever arm against gravity or complete full range of motion required to perform isokinetic evaluation in active mode. Therefore, previous studies used the passive mode for subjects with muscle weakness, such as children with cerebral palsy [10]. The selected variables were the time to peak force and agonist/antagonist ratio that reflects motor control in that children.Measuring the ratio between agonist/antagonist torques is of important value in strength training children with spastic diplegia as it shows the degree of motor control between them. Time to peak torque reflects ability of a muscle group to produce strength rapidly [32]. Statistical analysis of the post treatment results of the two groups revealed significant improvement in the measured variables.

The significant improvement obtained in the post-treatment mean values of the measuring variables of the control group may be attributed to the effect of the selected exercise program, which was directed toward facilitating normal postural control, balance and equilibrium reactions and stretching exercises. This agrees with a study that supported the effectiveness of neurodevelopmental treatment in different types of cerebral palsy [41].

Improvement in the post treatment mean values of the study group may be attributed to the strength program provided by the UEU which comes in agreement of the review of strength training programs; that studied a training program for a minimum of six weeks may be sufficient to improve lower extremity muscle performance and increase the ability to generate muscle force in children with CP [6, 7].

The results of the present study comes in agreement with many authors who concluded that children with normal motor development, as well as with spastics diplegia increase their capacity to generate strength when submitted to a resistive training [4, 16]. However, others showed that CP children when compared with normal children show less capacity to generate strength in all muscle groups of the lower limbs, except for the hip extensors which contradict with this study [40].

Systematic reviews have shown the benefits of strengthening exercises applied on CP patients [38]. The UEU was effective for twenty-four strength training sessions which improved function and significant gains in manual coordination following practice of isolated, simple joint movements during strength training. Improved motor skills may be due to effective use of feed forward control and improved stabilization [24].Choosing the UEU training program in strength training Individuals with cerebral palsy is of advantage of decreasing the effect of gravity on spastic muscles [24].

As impairments in cerebral palsy children involve a variable range of functional disabilities, the children need comprehensive rehabilitation therapy. It is important to determine the effects of therapeutic interventions on motor function with reliable and valid tests [20].

The GMFM-88 is commonly used in the evaluation of gross motor function in children with cerebral palsy CP. Both the reliability and the responsiveness of the GMFM-88 are reasonable for measuring gross motor function in children with CP [20]. The original GMFM, an 88-item measure also known as the GMFM-88, is observational measure specifically developed to evaluate changes in gross motor function over time in children across the wide spectrum of ability levels in CP [8,31]. Because it allows quantitative evaluation of motor function, many studies have used the GMFM to assess the effectiveness of interventions in children with CP [22, 28, 36].

The measured items of standing represent areas with which many children with mild spastic diplegia have difficulty[25] and are activities that are more likely to be improved by a lower limb functional strength training program [18].

CONCLUSION

Improvement and preservation of function is one of the primary aims in the management of children with cerebral palsy, according to the results of this study we can conclude that increases in muscle strength resulted in maintenance of function and its improvement in spastic diplegia population.

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الملخص العربي

التحكم العضلي وظيفة الوقوف بعد تدريب القوة في حالات الشلل النصفي التقلصي السفلي

يعتبر قله القدرة على التحكم العضلي صفه بارزه لحالات الشلل المخي. الهدف من هذه الدراسة هو قياس التغيير في الوقت اللازم للوصول الي اعلي قوة ونسبه عمل العضلات والعضلات المعاكسة وظيفة الوقوف بعد تطبيق برنامج تقوية عضلات الطرفين السفليين باستخدام وحدة العلاج الموحدة. تم اجراء هذا البحث على اربعين طفلا مصابا بالشلل النصفي التقلصي السفلي من الجنسين (20 ولد و2 بنت). تتراوح اعمارهم من أربع الي ست سنوات (المستوي الرابع والخامس في مقياس الوظائف الكبيرة) وتم تقسيمهم عشوائيا الي مجموعتين متساويتين في العدد (المجموعة الضابطة ومجموعة الدراسة). وقد تم تقييم الوقت اللازم للوصول الي اعلي قوة ونسبه عمل عضلات الثني والفرد للطرفيين السفليين باستخدام جهاز بيو دكس كما قيمت وظيفة الوقوف باستخدام مقياس الوظائف الكبيرة قبل وبعد تطبيق العلاج لمدة ثلاث شهور. وقد اظهرت النتائج وجود فروق ذات دلالة إحصائية في نتائج المجموعتين قبل وبعد العلاج وعند مقارنة نتائج المجموعة الحاكمة بنتائج

مجموعة الدراسة بعد انتهاء الدراسة لصالح مجموعة الدراسة. وبناءان على النتائج يمكن الاستنتاج ان تمرينات التقوية باستخدام وحدة العلاج الموحدة يحسن من التحكم العضلي وظيفة الوقوف للأطفال المصابين بالشلل النصفي التقلصي السفلي.

الكلمات الدالة: الشلل الدماغي، التقلص السفلي المزدوج، التحكم العضلي، التقييم الحركي، وحدة العلاج الموحدة ، الوقوف