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Effect of Asymmetrical Paraspinal Pattern on Muscle Architecture in Children with Spastic Diplegia

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ABSTRACT
Background: In order to understand the architecture of the muscle, which is the perpendicular distance between the deep and superficial aponeurosis, muscle thickness is crucial. While, MRI and computed tomography are more expensive and time-consuming, 2D B-mode ultrasound makes it simple and reasonably rapid to quantify muscle thickness. **Purpose:** This study aimed to investigate the effect of asymmetry in paraspinal pattern on muscle thickness in children with spastic diplegia.
Patients and methods: A total of 16 children with spastic diplegia with mild neuromuscular scoliosis, from both gender and with a mean age of 5.63 ± 0.33 years, were recruited from Pediatrics Outpatient clinic, Faculty of Physical Therapy, Cairo University. Children were assessed using X-ray to detect the scoliosis and assess the asymmetry and ultrasonography was used to assess the muscle thickness which was conducted from two positions prone and standing at T8 level thoracic spine. **Results:** The statistical analysis revealed that there was significant difference in muscle thickness between both sides with greater muscle thickness at concave side compared to convex at level of T8 from prone position (P=0.014). No statistically significant difference was found in muscle thickness between convex and concave sides at level of T8 from standing position (P=0.327).
Conclusion: The asymmetrical paraspinal pattern can affect the muscle architecture with greater muscle thickness in the concave side than in the convex side in children with diplegia who have mild scoliosis.
Keywords: Asymmetry, Muscle thickness, Paraspinal pattern, Spastic diplegia, Cerebral palsy.

INTRODUCTION
Cerebral palsy (CP) is predominantly a neuromotor condition that influences movement, muscle tone, and posture. The underlying etiology is brain damage throughout the prenatal and neonatal periods [(1)].

Spastic diplegia is the most prevalent kind of spastic CP. A hypoxic white matter infarct in the periventricular regions may result in spastic diplegic CP. Bilateral lower limbs are the most affected, leading to problems with balance, coordination, and gait. Children with diplegia frequently exhibit greater lumbar spine lordosis, bilateral hip internal rotation, bilateral knee flexion, intoeing, and equinovalgus foot posture while standing [(2)].

Deficits in postural control in children with CP impact their motor activity and may hinder their ability to engage with their surroundings [(3)]. In this developing phase, the trunk is essential for both organizing balancing reflexes and preserving the postural control system. In order to perform functional tasks for limb movement, a solid foundation of support is also necessary, which is made possible by trunk control [(4)].

Neuromuscular deficits resulting from aberrant posture, loss of selective motor control, and poor trunk control and balance lead to poor posture control and major difficulties in daily living activities [(5)].

Scoliosis is a spinal deviation characterized by a lateral curvature and vertebral rotation inside the curve in which the Cobb angle assessed on an anterior-posterior radiograph should be at least 10 degrees and is invariably related with vertebral axial rotation [(6)]. It is also known as a 3-dimensional spinal deformity [(7)].

Although there are other neuropathic or muscular conditions that can cause neuromuscular scoliosis (NMS), such as CP, myelodysplasia, or muscular dystrophy, the primary underlying cause of NMS is the compromised function of the muscle forces pushing on the spine, which results in increasing trunk imbalance [(8)]. The most prevalent kind of scoliosis in children, idiopathic scoliosis (IS), has a frequency of up to 4%, whereas scoliosis linked to neuromuscular disorder can reach 90%. In contrast to the idiopathic variety, NMS is linked to a much greater risk of complications and financial burden, and it tends to advance even beyond skeletal maturity [(9)].

Muscle thickness is an essential area in researching muscle architecture since it is defined as the perpendicular distance between the deep and superficial aponeuroses [(10)]. Muscle thickness can be assessed readily and rapidly using 2D B-mode ultrasound, although MRI and computed tomography are more expensive and time-consuming [(11)].

This study aimed to assess the effect of asymmetrical pattern of paraspinal on muscle thickness in children with diplegic CP.

PATIENTS AND METHODS
Participants: A total of 16 children with diplegic CP, with age range from 4 to 6 years of both sexes, were

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recruited from Pediatric Outpatient Clinic, Faculty of Physical Therapy, Cairo University.

Inclusion criteria: All children had mild to moderate degree of spasticity ranged from 1 to 2 according to Modified Ashworth Scale [12]. Their motor function level was at level II and III according to Gross Motor Function Classification System (GMFCS) [13]. They had scoliotic deformity with Cobb's angle of 25 degree or less and they were able to follow instructions during evaluation procedures.

Exclusion criteria: The research excluded children with visual or auditory impairments, upper or lower limb structural abnormalities, lower limb and/or spine surgeries, and lower limb injections of botulinum toxin within the previous six months.

Outcome measures: All children completed the following assessment including assessment of muscle thickness of paraspinal muscles at level of T8 thoracic spine.

Procedures:

Assessment of muscle thickness:

Participants were tasked with using a B-mode ultrasound imaging instrument to determine their muscle thickness. During imaging certain precautions were considered in order to assure the measurement procedures including: (1) The position of the child, (2) The precise position of the measurement would be determined by anatomical definition. A different muscle thickness and maybe a different echo intensity were to be detected if the muscle was evaluated at a different place, (3) Muscle relaxation, to ensure maximum relaxation, it is sometimes necessary to take more time and (4) The correct position of the transducer in a transverse plane, and the system settings [14].

Prior to US imaging: In the prone position, participants were asked to palpate the spinous processes to mark T8.

Children would be imaged in two different positions: First, in a calm prone posture with their arms by their sides, and then, standing up straight and doing the same [15].

A cushion was positioned beneath the pelvis in the prone position in order to reduce thoracic kyphosis at T8. At the vertebral level (T8), US pictures were obtained from the right and left sides of the spine in both relaxed prone and standing positions. The youngsters would classify the left and right sides as either convex or concave. Parasagittal imaging of the deep thoracic paraspinal region would be performed using a normal US imaging methodology [16]. Prior to imaging the deep thoracic paraspinals at T8, the participant was placed in the prone position by the sonographer. The measurement of muscle thickness was taken while standing using electronic calipers. The measurement was made by measuring the distance between the inner border of the fascia between the deep thoracic paraspinals and superficial tissue and the most posterior part of the zygapophyseal joints [17].

Ethical approval: The Research Ethical Committee of Cairo University's Faculty of Physical Therapy gave its approval to this cross-sectional study. Before the research was conducted, all children and their parents were informed of its goal and methodology. Every caregiver for the participant gave his informed permission. The Helsinki Declaration was followed throughout the course of the investigation.

Statistical analysis

SPSS version 25.0 on Windows 10 was used to code, input, and analyze the gathered data. Relative percentages and frequencies were used to report the qualitative data. To determine the difference between two or more sets of qualitative characteristics, the X^2-test was utilized. The mean. ± SD, was used to report quantitative data. A p-value was considered significant if it was 0.05 or less.

RESULTS

A total of 16 children with spastic diplegia participated in this study. Their age ranged from 4 to 6 years with a mean value of 5.63 ± 0.33 years. Their weight ranged from 20 to 22 kg with a mean value of 21.25 ± 0.77kg. Their height ranged from 115 to 120 cm with the mean value of 117.75 ± 1.35cm. Their body mass index (BMI) ranged from 15.1 to 15.4 kg/m^2 with mean value of 15.24 ± 0.07kg/m^2. Their Cobb's angle ranged from 10 to 25 with a mean value of 13.06 ± 4.55 degree (Table 1).

Table (1): General characteristics of children with spastic diplegia

	Mean ± SD	Minimum	Maximum
Age (year)	5.63 ±0.33	5.11	6
Weight (kg)	21.25 ±0.77	20	22
Height (cm)	117.75 ±1.35	115	120
BMI (kg/m^2)	15.24 ±0.07	15.1	15.4
Cobb's angle (degree)	13.06 ±4.55	10	25

The children gender distribution for categories boys and girls were 6 (37.50%) and 10 (62.50%), respectively. The children spasticity distribution for categories 1 and 2 were 10 (62.50%) and 6 (37.50%) respectively. The scoliotic curve distribution for categories right and left were 6 (37.50%) and 10 (62.50%) respectively. The GMCS level distribution of children for categories level 2 and level 3 were10 (62.50%) and 6 (37.50%) respectively (Table 2).

Table (2): Frequency distribution of gender, spasticity, GMSCS level and scoliotic curve in participated children

		Number	Percentage
Gender	**Boys**	6	37.50%
	Girls	10	62.50%
Spasticity	**1**	10	62.50%
	2	6	37.50%
Scoliosis type	**Right**	6	37.50%
	Left	10	62.50%
GMCS level	**Level 2**	10	62.50%
	Level 3	6	37.50%

At prone position, the mean muscle thickness for convex and concave sides at level T8 were 1.27 ± 0.10 and 1.39 ± 0.19 respectively. The mean difference of muscle thickness between convex and concave sides at level T8 was 0.12. The statistical analysis revealed that there was significant difference ($P<0.05$) in muscle thickness ($P=0.014$) between both sides with greater muscle thickness at concave side compared to convex at level T8 from prone position. At standing position, the mean muscle thickness of the convex and concave sides at level T8 were 1.41 ± 0.24 and 1.42 ± 0.25 respectively. The mean difference of muscle thickness between convex and concave sides at level of T8 was 0.01. The statistical analysis revealed no statistically significant difference in muscle thickness between convex and concave sides at level of T8 from standing position ($P=0.327$) (Table 3).

Table (3): Comparison of muscle thickness between convex and concave sides at level T8 from prone and standing positions

	Muscle thickness at level T8			
	Prone position		Standing position	
	Convex (n=16)	Concave (n=16)	Convex (n=16)	Concave (n=16)
Mean ± SD	1.27 ±0.10	1.39 ±0.19	1.41 ±0.24	1.42 ±0.25
Mean difference	0.12		0.01	
t-value	2.765		1.013	
P-value	0.014*		0.327	

*: significant

DISCUSSION

This study aimed to assess the effect of asymmetrical pattern of paraspinal muscles on muscle thickness in children with diplegic CP. Spastic diplegia is the most prevalent type of CP that may develop contractures and deformity in their spine and extremities that result from their impairments in gait and mobility. Diplegic children with spasticity may exhibit abnormal synergies of movement including associated reactions and extensor or flexor patterns of movement with effort. They may adopt poorly to movement, which lead to poor balance, less inhibition of movement, and less speed of movement compared to their peers without spasticity. They could have decreased postural stability, which causes them to lose strength, balance, and skill in activities of daily living. This can lead to issues with posture, balance, and controlling their gait. Furthermore, they frequently have delayed gross motor function development, which has been linked to functional results [(18)].

Children with CP have motor impairment mostly due to issues with trunk control [(19)]. Static trunk control and active trunk movements, both inside and outside the base of support, were both rather easy for kids with spastic diplegia. Additionally, it showed that children with CP exhibit a pronounced impairment in trunk control [(20)]. Muscle thickness was assessed using a B-mode ultrasound imaging instrument. In recent years, US imaging has emerged as a preferred approach for examining muscle morphologic properties and dimensions. The dependability of this approach has been tested and done with varied designs and quality, and the reported values of rehabilitative US have a wide range [(21)].

The findings of this study revealed that the muscle thickness of the deep thoracic muscles from prone position was greater at the concave side compared to convex side at level of T8 within children having scoliosis at the thoracic level with the apex at the level of T8. No statistical significant difference was found in muscle thickness between convex and concave sides at level of T8 from standing position, these findings may be due to changes in muscle morphology that occur on the concave side from the prone position when the muscle is in the relaxed position but there is no significant difference between muscle thickness in the standing position contrary to the results in the prone position. In order to anchor the spine in a posture that resists gravity, a child with CP diplegia who has minor scoliosis may contract the deep thoracic paraspinal muscles in a different way [(22)].

Furthermore, **Stetkarova *et al.*** [(23)] employed muscle biopsy and electrophysiology to investigate the variations in the composition of muscle fibers in the convex versus concave paraspinal thoracic muscles. They found that scoliosis affects muscles on both sides of the curve, with the convex side having more type I muscle fibers and the concave side having fewer. Due to certain muscle abnormalities such muscle atrophy and alterations in the kind of muscle fibers, people with scoliosis have been found to have bilateral muscle weakening on both sides of the curve, particularly in the multifidus muscle, in comparison with people in good health [(24)]. Scoliosis is linked to a number of motor and sensory deficits. Proprioceptive abnormalities, asymmetries, muscular imbalance between the two sides of the spine, and neurogenic diseases of the paraspinal muscles as shown by stretch reflex responses are some of these. Problems in balance control are caused by these deficits [(7)].

The current study's findings are consistent with those of **Zapata *et al.*** [(22)] who investigated paraspinal muscle asymmetries in scoliotic individuals. In the prone position, they discovered muscle asymmetry and notable variations in the thickness of the deep thoracic paraspinal muscles on both sides of the curve, with the concave side having more muscle than the convex side, but there was no difference between the two sides of the curve when standing. A comparison was also made between the dominant hand side of the curve in the control group and the concave side of the curve in the scoliosis group, since the greater of the two sides was anticipated. At T8, the scoliosis group's concave side of the curve had noticeably thicker muscles than the dominant side of the control group in the relaxed prone position. Also, **Yeung *et al.*** [25] who their study used MRI to objectively assess the morphological alterations of paraspinal muscles between IS patients with different thoracic curve severity and normal controls. They discovered that the concave side's paraspinal muscles had greater signal intensities and fatty infiltration, both of which were positively connected with the curve's severity.

CONCLUSION

The results of this study showed that the asymmetrical paraspinal pattern can affect the muscle architecture with greater muscle thickness in the concave side than the convex side in children with diplegia who have mild scoliosis.

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