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Original Research Article

Lower Limb Muscle Thickness and Functional Performance in Children with Cerebral Palsy

Abdel Hamid N. Deghidi[1*], Instar S. Waked[2*], Ashraf Deghidi[3]

[1]Lecturer of Physical Therapy, [2]Assistant Professor,
[*]College of Applied Medical Sciences, Majmaah University, Kingdom of Saudi Arabia.
[3]Specialist of Pediatric, Ministry of Health, Kingdom of Saudi Arabia.

Corresponding Author: Abdel Hamid N. Deghidi

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ABSTRACT

Objective: The aim of the study was to investigate the relationship between lower limb muscle thickness and functional Performance between cerebral palsy (CP), Down syndrome and normally developed children.
Subjects: fifty children participated: 33 CP and 6 Down syndrome and 11 normally Developing children.
Methods: Ultrasonography and a manual muscle tester were used for measuring the thickness and strength of knee extensor and ankle plantar flexor muscles. The Gross Motor Function Measure (GMFM) and Pediatric evaluation disability inventory (PED) were used to evaluate level of gross motor and functional performance.
Results: Knee extensor thicknesses of CP and Down syndrome children were thinner than those of normally developing children. Strengths of knee extensor and ankle plantar flexor showed differences being strongest in normally developing children, followed by Down syndrome, and CP. Subjects in the examination of GMFM, there were no significant differences between CP and Down syndrome. A decline in social function of Down syndrome subjects was found in the examination of PEDI.
Conclusion: CP and Down syndrome children had smaller muscle thicknesses and strengths than those of normally developing children, and lower gross motor function and mobility level.

Key words: Cerebral palsy, Muscle thickness and functional Performance.

INTRODUCTION

Cerebral palsy (CP) involves a set of neurophysiological impairments caused by a global reduction in subcortical activity that compromises the activity of corticospinal and somatosensory circuits. [1-6] CP results in diminished activation of the central nervous system during the execution of movements. [4] A reduction in motor cortex excitability in children is associated with poor motor development. [7] Children with cerebral palsy show weakened muscle due to lack of motor unit activation and thickness of 50% of small muscles, compared to children with normal development. [8] cerebral palsy with capability of independent ambulation also had limitation on muscle contraction in that its greatest ability of muscle contraction only reached 52% of that of normally developed children, [9] regular physical activity ameliorates, but does not prevent age-related atrophy of lower extremity muscles. [10] The Gross Motor Function Measure (GMFM) and computerized gait analysis are commonly used to assess patients with cerebral palsy (CP). Knee extensor strength correlated directly with the GMFM. [11] 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. [12] But, few studies of the muscle structure and body function of cerebral palsy subjects have been performed. The purpose of the study was to investigate the relationship between lower limb muscle thickness and functional Performance between cerebral palsy (CP), Down syndrome and normally developed children.

MATERIALS AND METHODS

Design: This study received approval from the Human Research Ethics Committee of Majmmah University (Saudi Arabia) and was conducted in accordance with the ethical principles established by the Declaration of Helsinki. All parents or guardians agreed to the participation of their children by signing a statement of informed consent. The following were the inclusion The subjects of this study were 33cerebral palsy children (17 males and 14females) who were diagnosed as having diplegic cerebral palsy (GMFCS Level I, n=10; Level II, n=5; Level III, n=18) and were receiving physical therapy at Majmaah Comprehensive Rehabilitation Center, 11normally developing infants (7 males and 4 females), and 6 Down Syndrome subjects (4 males and 2 females), a total of 50 subjects. The specific selection criteria were as follows: no orthopedic surgery within the last 6 months, and no botulin treatments of the lower limbs during the previous 3 months. The following were the exclusion criteria: history of surgery or neurolytic block in the previous 12 months; orthopedic deformities; epilepsy; metal implants in the skull or hearing aids).

Measurement: Movable ultrasonic waves (Mysono U5, Medison Korea, 2009) were used to measure the muscle thicknesses of the rectus femoris and gastrocnemius. Subjects were made comfortable in the prone position with knee extension, and the distance between the superior aponeurosis and the inferior aponeurosis of the gastrocnemius was measured as the thickness of the gastrocnemius. [13] An intra-rater reliability of r = 0.98:1.0, and an inter-rater reliability of r = 0.93:0.98 have been reported for ultrasonic waves imaging. [14]

Nicholas Manual Muscle Tester, Model 01160; Lafayette Instrument, Lafayette, IN, a commercial device was used to assess isometric knee extensor muscle strength. The children were seated in sitting position with their knees flexed at 90^0 and resistance was given by the examiner anteriorly 5 cm proximal to lateral malleolus. The examiner gradually applied force over one second to allow the child to adjust and recruit a maximum number of muscle fibers. Three attempts at each muscle group were recorded. The first attempt was used for familiarization and a score was obtained by averaging the second and third attempts. Hand-held dynamometers have been shown to be reliable instruments for measuring knee extension strength, [15] and they have been used successfully in measuring muscle strength in children with spastic diplegia. [16] An intra-rater reliability for the manual muscle tester of r = 0.84:0.99, and an inter-rater reliability for the manual muscle tester of r = 0.84:0.94 have been reported. [17]

Gross motor function. The gross motor performance was tested with GMFM-88. It consists of 88 items within 5 dimensions: (A) lying and rolling; (B) sitting; (C) crawling and kneeling; (D) standing; (E) walking, running and jumping. The items are scored using a 4-point scale (0, 1, 2, and 3) and the scores are presented in percentages, and in this study only dimensions D and E were assessed. Inter-rater reliability for GMFM of r = 0.77, a test-retest reliability for GMFM of r = 0.88, and intra-rater reliability for GMFM of r = 0.68 have been reported. [18]

The Pediatric evaluation disability inventory scale (PEDI) allows a quantitative evaluation of functional performance. This questionnaire is administered in interview format to one of the caregivers, who offers information on the child's performance on routine activities and typical tasks of daily living. The test is composed of three parts. The first part addresses abilities in the child's repertoire, which are grouped into three functional domains: self-care (73 items), mobility (59 items) and social function (65 items). Each item on this part receives a score of either 0 (child is unable to perform the activity) or 1 (activity is part of the child's repertoire). The score of each domain is determined by the sum of the items. [19,20]

Procedure: Muscles thickness was assessed by ultrasonography for gastrocnemius muscle by measuring tibia length (TL) from the most prominent point of the lateral malleolus to the fibular head. Point at the top 25% of TL was marked with a fiber-tip pen. The US image was obtained at the marked point following the recommendations of Bénard, et al. [21] Rectus femoris muscle thickness was assessed by measuring the femur length (FL) from the distance between the greater trochanter of the femur and the articular cleft between the femur and tibia condyles. US image was obtained at marked point 50% of the thigh length. [22]

Strength of knee extensors was assessed using a handheld dynamometer. The children were seated in sitting position with their knees flexed at 90^0 and resistance was given by the examiner anteriorly 5 cm proximal to lateral malleolus. The examiner gradually applied force over one second to allow the child to adjust and recruit a maximum number of muscle fibers. Three attempts at each muscle group were recorded. The first attempt was used for familiarization and a score was obtained by averaging the second and third attempts.

Gross motor function was tested with GMFM-88.It consists of 88 items within 5 dimensions: (A) lying and rolling; (B) sitting; (C)crawling and kneeling; (D) standing; (E) walking, running and jumping. The items are scored using a 4-point scale (0, 1, 2, and 3) and the scores are presented in percentages, and in this study only dimensions D and E were assessed.

Statistical analysis

The SPSS 18.0 program was used for statistical analyses. The Shapiro-Wilk test was used for determination of the general properties and variables of the subjects. Independent t test was used for the comparison of GMFM and WeeFIM between cerebral palsy and Down syndrome subjects, and one-way ANOVA was performed for comparison of the means of muscle thickness and strength among the subjects groups. A post-hoc test using the Scheffe method was employed for comparison of each group. A p value under 0.05 was considered significant.

RESULTS

General characteristics of subjects for study are as follows (Table 1). Differences in muscle thicknesses of the rectus femoris and gastrocnemius according to the posture are presented in Table 2. The average thickness of the rectus femoris in the standing position was 13.19 mm for normally developing infants, 12.82 mm for cerebral palsy subjects and 11.19 mm for down syndrome subjects, with significant differences among the groups ($p<0.05$). The average thickness of the rectus femoris in the supine position was 16.23 mm for normally developing infants, 14.25 mm for cerebral palsy subjects, and 11.73 mm for down syndrome subjects, with significant differences among the groups ($p<0.05$).

The average strength of the knee extensor was 18.21 kg for normally developing infants, 8.22 kg for cerebral palsy subjects and 12.21 kg for down syndrome subjects, with significant differences ($p<0.01$). The average strength of the ankle plantar flexor was 15.77 kg for normally developing infants, 5.91 kg for cerebral palsy subjects, and 8.02 kg for down syndrome subjects, with significant differences among the groups($p<0.01$). Normally developing infants'rectus femoris was thicker than that of cerebral palsy, and Down syndrome subjects, according to the post hoc test. Knee extensor and ankle plantar flexor strengths were the strongest for normally developing infants, followed by Down syndrome and cerebral palsy subjects, according to the post hoc test.

The results of comparison of the GMFM, and PEDI between cerebral palsy and Down syndrome are presented in Table 3. There was a significant difference in the average scores of social function in PEDI: 53.3 for cerebral palsy subjects and 46.2 for Down syndrome subjects ($p<0.05$)

Table 1: General characteristics of the participants

	Cerebral Palsy (N=33)	Down Syndrome (N=6)	Normal Development (N=11)
Sex (Male/Female)	17/14	4/2	7/4
Age (Month)	68.6 (15.2)	58.2 (14.2)	80.4 (22.0) A
Height (Cm)	110.3 (5.6)	105.4 (7.2)	122.6 (12.7)
Weight (Kg)	19.3 (6.2)	23.6 (4.0)	22.3 (3.6)

Table 2: Comparison of muscle thickness and strengths among the groups

		CP n=33	*DS n= 6*	*NDI n=11*
Muscle thickness (mm)	RF in standing	11.22 (1.95)	12.69 (2.63) b	13.79 (1.94) *, a
	RF in Lying	14.25 (2.53)	11.73 (1.85) b	16.23 (3.17)*, a
	Gastrocnemius standing	12.90 (2.57)	13.53 (3.16)	12.42 (1.42)
	Gastrocnemius Lying	13.82 (3.78)	13.54 (3.88)	14.41 (2.52)
Muscle strength (Leg)	Knee extensors	8.22 (3.92)	12.21 (6.04) d	18.21(6.05) *, c
	Ankle Planter flexor	5.91 (3.97)	8.02 (2.94) d	15.77 (8.05) *, c

Table 3: Comparison of GMFM and PEDI between CP and DS

		CP (n=33)	*DS (n=6)*
GMFM (Score)	Lying &Rolling	99.22(7.33)	102(1.15)
	Sitting	97.05(9.05)	98.33(3.23)
	Crawling	82.44(15.32)	85.14(22.03)
	Standing	55.78(33.44)	71.21(33.92)
	Walking, Running &Jumping	39.77(34.32)	61.68(40.25)
	Total	74.46(18.75)	83.48(20.11)
PEDI(Score)	Mobility	34.23(6.25)	36.16(7.13)
	Self – care	36.4(5.2)	37.3(2.6)
	Social function	53.3(3.4) *	46.2(3.4)

Values are mean (SD). *p<0.05 from mean between the two groups

Values are mean (SD). NDI: normally developing infants; CP: cerebral palsy; DS: mental retardation; RF: rectus femoris; *p<0.05 from mean among the three groups; a, NDI is significantly greater than CP and DS; b, DS is significantly greater than Cp; c, NDI is significantly stronger than CP and DS; d, DS is significantly stronger than CP according to the post hoc test.

DISCUSSION

A previous study of the muscle structure of cerebral palsy subjects investigated the formation of the gastrocnemius and hamstrings using ultrasound and reported the pennation angle of the gastrocnemius was 10 degrees, the pennation angle of the plantar flexor was 10 degrees, and the pennation angle of the dorsi flexor was 10 degrees. [23] Compared to normally developing infants, in cerebral palsy subjects, the pennation angle of the calf muscle and the range of motion of the ankle were smaller, and this may be a cause of decrease in physical activity. Therefore, structural problems of the muscle are the main factor affecting muscular function and decrease in activity. [24] The gastrocnemius, one of the lower extremity muscles, plays an important role in supporting weight in gait, and in adjusting the angle of the ankle in the stance and swing phases. When compared with normally developing infants, and there were significant differences in cerebral palsy subjects' gastrocnemius and rectus femoris thicknesses. [23] Significant differences between the thickness of the postural rectus femoris of children with cerebral palsy and Down Syndrome were shown in this study ($p<0.05$), as well as significant differences in knee extensor and plantar flexor strengths ($p<0.01$). These results agree the results of earlier studies. [25] The rectus femoris and gastrocnemius of children with Down syndrome were thicker than those of children with Cerebral Palsy; however, knee extensor and plantar flexor strengths of children with Down syndrome were stronger. Generally, strength is proportional to the diameter of the muscle. Compared to children with cerebral palsy, the rectus femoris and gastrocnemius of children with Down syndrome were thicker and their strengths were less strong that is because of muscular pseudo atrophy. In the comparison of the GMFM and PEDI between children with cerebral palsy and Down syndrome, there were no significant differences except for the item of social function. However, cerebral palsy children showed limitations in basic ability of movement which appeared as lower scored in the items of standing, walking, running in GMFM. Limitations of functional activity were shown by both groups of children in the PEDI. Children with Down syndrome showed a significant difference from children with cerebral palsy in the item of social function showing problems with that is necessary for social activity. Because of the small sample size and disparity between the different groups of children. In addition, this study only compared muscle thickness, strength and function, standards of activity and participation using cross sectional design. Therefore, further correlation analysis of each item is required.

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