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Relationship between Isometric Muscle Strength and Gross Motor Function in Children with Unilateral Cerebral Palsy: A cross-sectional study

Omnya Samy A. Ghoneim [1], Naglaa A. Zaky [2], Angham M. Adel Ahmed [3], Alshimaa Mokhtar Darwesh [4], Fatma O. Rohoma [5], and Wael O.A. Abd El-khalek [6]

1. Lecturer, Department of Physical Therapy for Pediatrics and Pediatric Surgery, Faculty of Physical Therapy, Badr University in Cairo, Egypt; Omnia.samy@buc.edu.eg; ORCID: 0000-0002-0780-5149
2. Professor, Department of Physical Therapy for Pediatrics, Faculty of Physical Therapy, Cairo University, Egypt; naglaaomsa_m@hotmail.com; ORCID: 0000-0001-7090-0256
3. Lecturer, Department of Physical Therapy for Neurology and Neurosurgery, Faculty of Physical Therapy, Egyptian Chinese University, Cairo, Egypt; pt.angham@yahoo.com; ORCID: 0000-0002-3484-8566
4. Lecturer, Department of Physical Therapy for Cardiovascular Respiratory Disorders and Geriatrics, Faculty of Physical Therapy, Egyptian Chinese University, Cairo, Egypt; Oshosh46@gmail.com; ORCID: 0000-0003-2442-2569
5. Lecturer, Department of Physical Therapy for Women Health, Faculty of Physical Therapy, Egyptian Chinese University, Cairo, Egypt; Fatma.rohouma@gmail.com; ORCID: 0000-0001-6860-3703.
6. Lecturer, Department of Basic Sciences, Faculty of Physical Therapy, Badr University in Cairo, Egypt; doctorwael2006@hotmail.com; ORCID: 0000-0002-7429-7586.

Corresponding author: Omnya Samy A. Ghoneim

Email: Omnia.samy@buc.edu.eg; omnyasamy90@gmail.com

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Abstract: Objective: Patients with cerebral palsy (CP) often experience muscle weakness, resulting in severe impairments that have a negative impact on their ability to perform functional tasks. The current study investigated the association between isometric muscular strength and gross motor performance in children with unilateral cerebral palsy (UCP).

Methods: This cross-sectional study was conducted at Private Pediatric Rehabilitation Centers and the Outpatient Clinic at the Faculty of Physical Therapy, Badr University in Cairo, Egypt. The study included 97 children with UCP. The maximum isometric muscle strength of the knee extensors, knee flexors, hip abductors, hip extensors, and paretic lower-limb hip flexors was evaluated by a hand-held dynamometer. The Gross Motor Function Measure (GMFM) of jumping, walking, running, and standing dimensions were determined using the GMFM-66.

Results: Knee flexors, knee extensors, hip extensors, hip abductors, and hip flexors showed statistically significant positive correlations with the GMFM-standing and walking dimensions ($p < 0.001$).

Conclusion: Gross motor function significantly correlates with isometric muscle strength in UCP subjects who ambulated with or without an assistive device. This study revealed that strong muscles are required for standing and walking, particularly at the hip and knee joints..

Keywords: *Gross motor function; Cerebral palsy; unilateral spasticity; hemiplegia; muscle strength*

Introduction

CP represents a collection of posture and movement disorders due to a non-progressive interference with the developing brain [1]. The Surveillance of Cerebral Palsy in Europe (SCPE) collaboration recommends using unilateral or bilateral to describe the distribution. It divides the four main categories of motor tone into spastic, dyskinetic, ataxic, and mixed [2].

Muscle weakness is one of the main complications of CP. This condition develops due to inactivation-learned nonuse, insufficient selective motor control, and central nervous system dysfunction. All CP subtypes are characterized by muscle weakness, and it is evident that CP patients' muscles are weaker than those of typically developing children **[**3**]**. The weakness observed in CP is due to altered brain pathways and muscular tissue alternations. Depending on the muscle group, there is a 6%-59% decrease in lower limb muscle strength compared to individuals with normal development [4].

Children with UCP demonstrate persistent posture and movement issues that mainly affect one side of the body. Children with muscle weakness and spasticity develop musculoskeletal deformities that impede their walking ability [5].

Muscle strength is directly correlated to motor function; therefore, muscle strength and selective motor control must be assessed as part of the examination protocol for children with CP to achieve the best possible functional results [6]. Muscular force can be evaluated using isometric, isotonic, and isokinetic methods. To measure muscle strength, the target muscle group must contract to the maximum capacity; however, this might be challenging due to cognitive constraints and higher co-contractions between agonists and antagonists. Patients should assist the assessor when necessary. Manual muscle testing, which involves measuring the maximum repetition of functional exercises or employing an isokinetic dynamometer and a hand-held dynamometer, is frequently used to assess muscular force [3].

In neurological rehabilitation, the GMFM is frequently used to evaluate the gross motor function in children with CP. Interventions may be evaluated in light of the natural history of motor development in CP, as described by GMFM **[**7**]**.

Gross motor function and gait are thought to be directly correlated with muscle strength; muscular strength increases function level, and vice versa. However, it is still unclear whether the weakness is the cause of the functional abnormalities reported in patients suffering from CP because researchers have objectively reported strength in individuals with upper motoneuron injury more frequently than they have objectively measured strength [8]. This study aimed to explore the relationship between isometric muscular strength and gross motor abilities in children with UCP.

METHODS

Sample size

Based on MedCalc® V12.7.5, Ostend, Belgium, 88 participants were required to reach a 95% confidence level and a power of 80. To compensate for potential losses, 10% was added; hence, the total number of participants was 97.

Ethical approval

The Ethics Review Committee, Faculty of Physical Therapy, Cairo University, approved this study (No: P.T.REC/012/003982). Following an explanation of the study's objectives and prospective registration in the Clinical Trials Registry (NCT05614167), a written informed consent form was collected from all patients' parents or legal guardians.

Study design

A cross-sectional study was conducted at Private Pediatric Rehabilitation Centers and the Outpatient Physical Therapy Clinic, Faculty of Physical Therapy, Badr University in Cairo. All children aged 6 to 12 with UCP and Gross Motor Function Classification System (GMFCS) levels I and II were enlisted utilizing a straightforward random sampling technique. Exclusion criteria included the inability to perform tests, comprehend verbal commands, or structural deformities in lower limb joints and bones.

Outcome measures

Muscle strength dynamometer/isometric muscle strength measurements

A hand-held dynamometer was used to measure the isometric muscular strength of the hip flexors, abductors, knee flexors, and extensors (The JTECH Medical Commander Echo Manual). It consisted of the Commander Echo Console, the Commander Echo Wireless Manual Muscle Tester, and a Specified Power Supply (Battery Charger) (PW006) for charging the Commander Echo Console and Commander Echo devices (Fig. 1).

Muscle Tester Dynamometer Specifications:

- The Muscle Tester was designed to fit comfortably in the therapist's palm during muscle testing. It allowed testing with both hands. Its slim profile and ergonomic design aided in rollover prevention.
- Intelligent load cell technology developed by Axis Compensation maintains accuracy even when off-center force is applied.
- It measured 670 Newton (N) for potent performers.
- Test protocols could be customized based on the number of tests, threshold, Newton, kilograms, or pounds, and the number of repetitions.

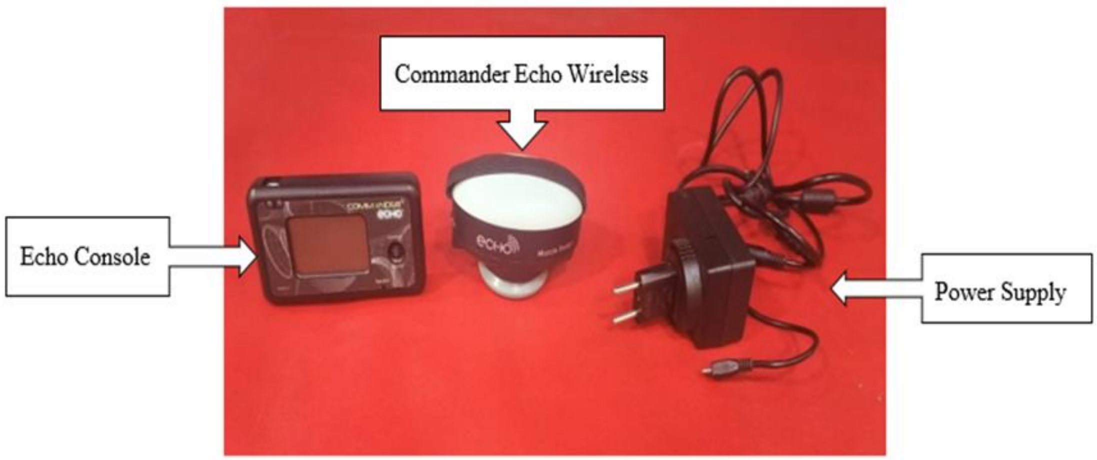


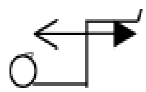
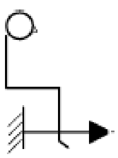
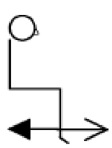
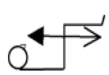
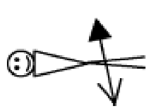
Fig. 1. The components of Muscle strength dynamometer Medical Commander Echo

Before initiating the test, the default settings, unit of measurement (N), number of tests (5), and number of repetitions (3) were verified.

In a "make" test, the peak force (measured in N) was determined by the child pushing against the dynamometer as forcefully as possible for three seconds while the investigator held the dynamometer steady. For the analysis, the three-repetition average score was used [9].

The subjects were examined while lying on their backs to evaluate their hips. The participants underwent testing while seated to measure their knee flexors and extenders. The participant's positioning and the device are depicted in Table 1 and (Fig. 2) A joint with a zero-degree angle was in neutral alignment, not in flexion or extension [9].

Table 1. Positioning for lower extremity muscle testing.

Figure	Muscle group	Body posture	Position of the limbs	Positioning of the dynamometer
	Hip extensors	Supine	Hip and knee flexed to 90◦	3 cm proximal to the posterior surface of the knee on the posterior thigh
	Knee extensors	Sitting	Straight trunk, crossed arms, hips, and knees flexed to 90 degrees, and unsupported feet	The anterior surface of the leg, 5 cm proximal to malleoli
	Knee flexors	Sitting	Straight trunk, crossed arms, hips, and knees flexed to 90 degrees, and unsupported feet	The posterior surface of the leg, 5 cm proximal to malleoli
	Hip flexors	Supine	Hip and knee flexed to 90◦	3 cm proximal to the patella in the anterior thigh
	Hip abductors	Supine	The hip is neutral in all planes.	The lateral surface of the thigh and closest to the knee

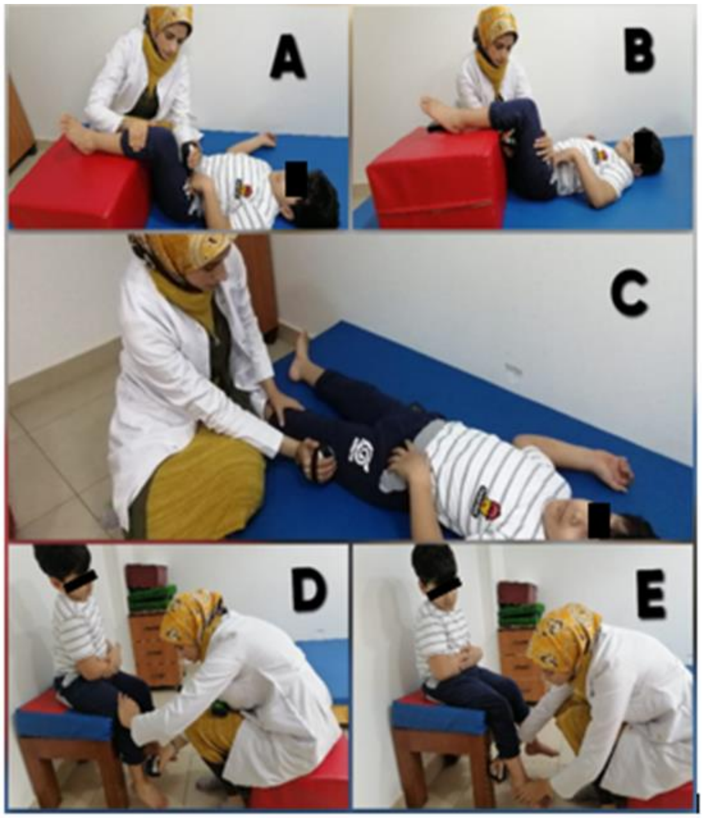


Fig. 2. Hand-held dynamometer test placement for six lower extremity muscle groups: (A) hip flexion, (B) hip extension, (C) hip abduction, (D) knee extension, and (E) knee flexion

GMFM

The GMFM-66 is an observational validated clinical test used to assess gross motor function in children with CP. It consists of 66 motor tasks (items) and is widely used to assess motor skills in children with CP [10].

Each GMFM item had a four-point scoring scale, and the assessment was broken down into five dimensions: A) lying, rolling; B) sitting; C) kneeling; D) standing; E) walking, running, and F) jumping **[**7**]**.

The GMFM-66 item scores were added to determine the raw and percentage scores for each of the five dimensions. Dimension E (24 items), which assessed motor activities while jumping, walking, and running, and the complete dimension D (13 items), which evaluated motor activities when standing on the GMFM-66, were the outcome measures in the current study.

A scoring key was utilized as a general guideline for evaluating each item. These scoring keys were 0 for "did not initiate," 1 for "initiated," 2 for "partially complete," and 3 for "completed." Then the dimensions of percentage scoring were calculated as follows:

Standing (Total Dimension D/39) x 100 = %

Walking, Running & (Total Dimension E/72) x 100 = %

Statistical methods

The results were analyzed using Statistical Package for Social Sciences (SPSS) V26 (IBM Corp., 2019). Quantitative data were demonstrated as percentages and numbers. Numerical data were expressed as mean ± Standard Deviation (SD). The Pearson or Spearman correlation coefficient tests were used to test the correlation between continuous data. The statistical significance threshold was established at $p \leq 0.05$.

RESULTS

Participants' characteristics

97 children with UCP were evaluated. The participants' mean age was 8.4 **±** 1.3 years. Females represented 48.5%. The participants' average height was 116.1 ± 5.4 cm, and their average weight was 26.8 ± 2.3 kg. About half of the patients (53.6%) experienced right hemiplegia. Subjects' clinical characteristics and demographics are displayed in Table 2.

Table 2. Participants' clinical characteristics and demographics

Characteristics	Total (n = 97)
Age (Yrs.): Mean ± SD.	8.4 ± 1.3
Weight (kg): Mean ± SD.	26.8 ± 2.3
Height (cm): Mean ± SD.	116.1 ± 5.4
Sex: n (%)	
Girls	47 (48.5%)
Boys	50 (51.5%)
Affected side: n (%)	
Left	53 (54.6%)
Right	44 (45.4%)
GMFCS: n (%)	
Level I	43 (44.3%)
Level II	54 55.7%)

Isometric muscle strength relationship with GMFM (Table 3)

(Fig. 3) shows a significant positive association between the GMFM-standing and the hip extensor, knee flexor, knee extensor, hip flexor, and hip abductor ($p < 0.001$). Furthermore, GMFM-walking and the hip abductor, hip extensor, hip flexor, knee flexor, and knee extensor demonstrated a statistically significant positive correlation ($p < 0.001$) (Fig. 4).

Table 3. Correlation between isometric muscle strength and GMFM standing and walking dimensions.

Muscle strength	GMFM- standing		GMFM-walking	
	r*	p-value	r*	p-value
Hip extensor	0.999	< 0.001	0.999	< 0.001
Hip abductor	0.986	< 0.001	0.998	< 0.001
Hip flexor	0.979	< 0.001	0.999	< 0.001
Knee flexor	0.999	< 0.001	0.998	< 0.001
Knee extensor	0.999	< 0.001	0.999	< 0.001

r, correlation coefficient

*The significance level was set at $p < 0.05$.

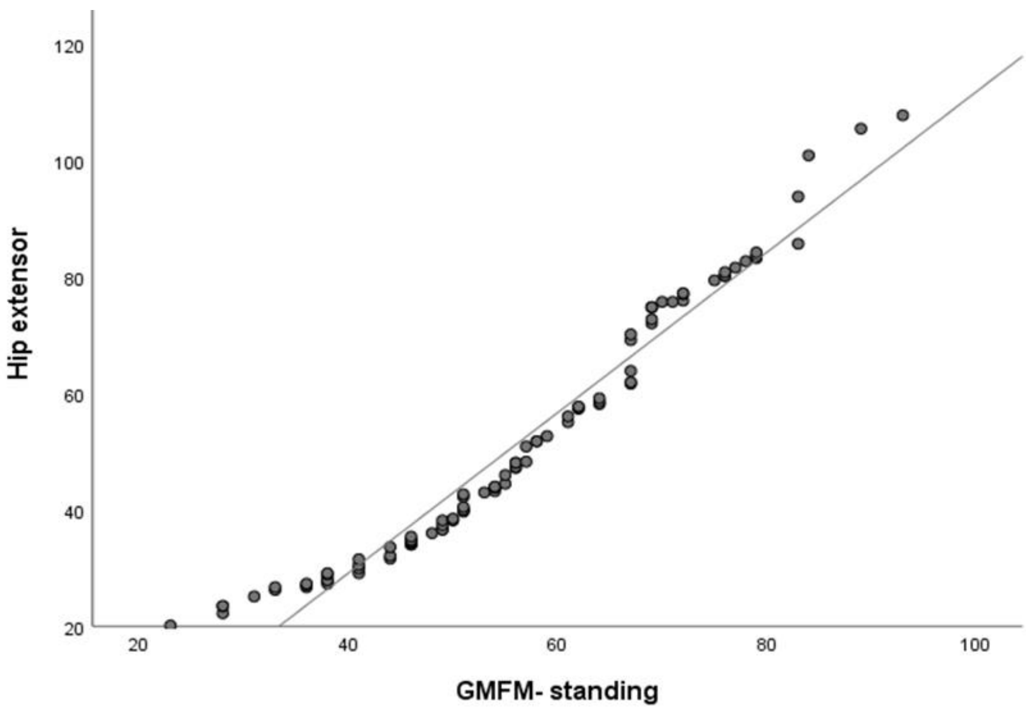


Fig. 3. Association between hip extensor isometric muscle strength and GMFM standing dimension

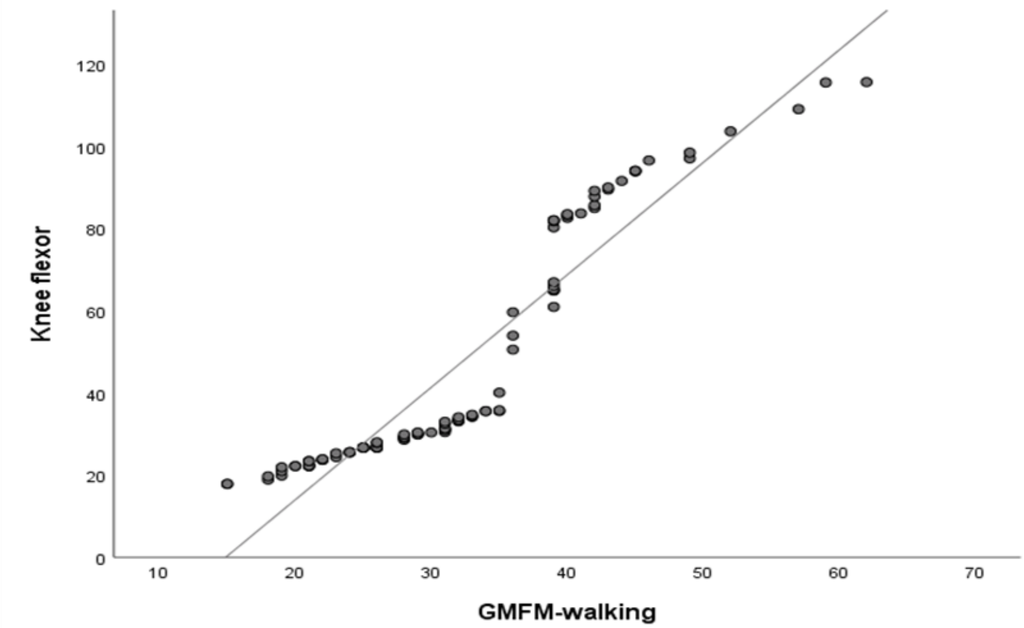


Fig. 4. Association between knee flexor isometric muscle strength and GMFM walking dimension.

Discussion

Based on the current study findings, strong positive and statistically significant correlations exist between the GMFM-standing and walking dimensions and isometric muscular strength in the knee flexors, knee extensors, hip extensors, hip abductors, and hip flexors.

Due to the limitations of the present study, the results cannot be extrapolated to children with lower functional levels or other clinical subtypes of CP. In contrast, children who reached GMFCS levels IV and V could not perform muscle strength tests because of their cognitive and physical limitations. The ankle plantar flexor and ankle dorsiflexor, which are crucial for gait and gross motor function, were excluded from the muscle strength testing because they could not produce enough isometric force. The relatively large sample size in this study, to establish sample variability in strength values, may impact the study results. Additionally, these results are consistent with a previous study that argued it was valid to evaluate a whole limb's strength by strength measurements from fewer muscle groups [11].

The portable dynamometer represents the gold standard for assessing isometric muscle strength. Using this straightforward, sensitive instrument for detecting muscular action, objective, reliable, and repeatable observations could be conducted in various populations [12].

Prior studies have considered the association between muscular strength and gross motor function in CP patients. They found a significant relationship between GMFM and muscle strength, showing that muscle strength and weakness impact one's capacity for walking and standing. Among these studies, Huenaertsa, 2019 [13] suggested that increasing muscle strength at the hip, knee, and ankle levels are crucial in improving CP function, which revealed significantly high correlations between strength and GMFM, as well as between selectivity and GMFM.

Noble, 2019 **[**14**]** suggested that children with CP who perform muscle-strengthening exercises to increase muscle growth may improve gross motor function, reflecting the significant correlation between muscle size and GMFM-66. Also, Cho and Lee, 2020 **[**15**]** reported that functional progressive resistance exercise is an efficient, safe, and practical intervention that can be used in the rehabilitation of children with CP, according to an analysis of the results of a six-week Functional Progressive Resistance Exercise (FPRE program).

The results of eight weeks of virtual reality treadmill training revealed that the improvement in gross motor function in spastic cerebral palsied children is due to muscle strength of the lower limbs and gait endurance [16].

The selective motor control (SMC) and muscle strength were significantly correlated with gross motor function in 327 children with CP aged 5-24 years; (poor SMC, r = −40.5 (2.0); moderate SMC r = −11.0 (2.0) with good SMC as reference category; for poor muscle strength, r = −8.6 (1.3), moderate muscle strength, r = −2.4 (0.8) with good muscle strength as reference category) [17].

Physical therapy for children affected by CP aims to promote involvement in daily activities, avoid the emergence of secondary conditions, including musculoskeletal abnormalities that affect health, and enhance motor function, such as adaptive function. The association between self-care, play, and motor ability are crucial to the motor outcomes of children with CP [18].

Gross motor function is a crucial factor in activity restriction and is related to how well an individual performs activities of daily living (ADLs). This finding agrees with the work of another study; the growth rate of gross motor function significantly influenced both the starting value and growth rate of ADL performance and that the growth rate of gross motor function significantly influenced both variables [8].

CONCLUSION

It is evident that in children with UCP, gross motor function and isometric muscle strength are related. According to this study, subjects with stronger muscles were more capable of standing and walking. Incorporating strength training into an exercise program may be essential for enhancing function. To further clarify the relationship between impairment and function and to determine whether a child with UCP could benefit from an intervention to improve functional outcomes, it is necessary to objectively measure the child's strength before and after the intervention.

CONFLICTS OF INTEREST STATEMENT

The authors have no conflicts of interest to declare.

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AUTHORS' CONTRIBUTIONS

Conceptualization, N.A.Z., O.S.A.G., W.O.A.A., F.O.R.; Methodology, O.S.A.G., W.O.A.A., F.O.R.; Data Analysis, A.M.A.A.; Writing and initial draft preparation, A.M.D, A.M.A.A.; Writing, review & editing, N.A.Z., O.S.A.G., A.M.D., F.O.R.; Visualization, N.A.Z., O.S.A.G., W.O.A.A. All authors have read and consented to the final, published version of the manuscript.

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