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ORIGINAL ARTICLE

Correlation between selective motor control and upper extremity function in children with hemiparesis

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ABSTRACT
Background: Impairedselective motor control is a common problem in children with hemiparesis; it interferes with upper extremity function and grip strength of the affected side.
Aim: To study the relationship between selective motor control and upper extremity function in children with hemiparesis.
Methods: This study included a convenient sample of 48 children with hemiparesis (age; four to eight years). The test of arm selective control, quality of upper extremity skill test, and hand held dynamometers were used to assess the selective motor control, upper extremityfunction and hand grip strength respectively.
Results: The results showed positive significant correlation ($p > 0.05$) between test of arm selective control with upper extremityfunction ($r=0.85$) and hand grip strength ($r=0.77$). Moreover, there was positive significant correlation between upper extremityfunction and hand grip strength ($r=0.72$).
Conclusion: Selective motor control is positively correlated with upper extremityfunction and hand grip strength in children with hemiparesis. The results help in the development of appropriate treatment programs for the rehabilitation of children with hemiplegia.
Keywords: Cerebral palsy; Hand grip strength; Selective motor control; Unilateral cerebral palsy; Upper extremity function.

INTRODUCTION
Cerebral palsy (CP) is a generic term describing common health problem which results in chronic permanent but modifiable motor disability which appears in early childhood secondary to trauma or malformation of immature brain [1,2].

Unilateral CP or hemiparesis is a common spastic subtype representing 20% to 30% of all types ofCP. In hemiparesis, themotor disabilities predominate in the affected upper extremity hindering the overall functional activity [3].

The primary impairments result from the damage in the central nervous system affecting tone, balance, and muscle strength. The secondary impairments that develop over time are soft tissue contractures and deformities due to the primary impairments and musculoskeletal growth [4]. The limited upper extremity function in children with hemiplegia is the primarily observed motor deficit, which significantly influence daily activity. Children with hemiplegia demonstrate impaired sensorimotor mechanisms, weakness, abnormal tone, impaired motor selectivity and spasticity that impede functional abilities of the affected upper extremity [5].

The location, timing, and extent of the brain lesion as well as the lesion of corticospinal tracts (CSTs) are considered as main determinants of motor impairments in children with unilateral CP [6]. Lesion of CST within the periventricular white matter is predominantly associated with impaired selective voluntary motor control (SVMC) [7]. SVMC describes the ability to voluntarily activate a group of muscles in a desired movement pattern and is considered as the main contributor to motor impairments in children with CP [8].

Previous studies have investigated the relation between lower extremity SVMC and functional performance in children with CP as gross motor function [9] and gait [10,11]. However limited studies are available regarding the relation between SVMC and upper extremity function. Therefore, this study aimed to investigate SVMC in relation to upper extremity function and hand grip strength in children with hemiparesis.

METHODS
Study design: This is an observational correlational study conducted from February to May 2021 in accordance with the Declaration of Helsinki.
Ethical considerations: The study was approved by the Institutional Review Board of Faculty of Physical Therapy; Cairo University (No:P.T.REC/012/003116) with the clinical trial registration number is NCT04695639. A signed written consent form was obtained from children 's parents/legal guardian before starting the study.
Sample size: To avoid type II error, a pilot study was performed prior to the study to estimate the sample size, using G*POWER statistical software (Franz Faul, Universitat Kiel, Germany; version 3.1.9.2) [Exact tests-correlational study, effect size = 0.4; $\beta=0.2$; $\alpha=0.05$] and indicated that the proper sample size for the current study is N=46.
Participants: This study contained a convenient sample of children with CP of both sexes selected from Faculty of Physical Therapy Outpatient Clinic, Cairo University, Al-Minya General Hospital Outpatient Clinic, Al-Minya Governorate and Physical Therapy Department Of National Institute Of Neuro Motor System. Eligibility criteria were 1) diagnosis hemiparesis; 2) age ranges from 4 to 8 years; 3) level I-III on Manual Ability Classification System (MACS); 4) spasticity grade 1 to 2 on Modified Ashworth Scale (MAS) and 5) level I-III on Gross Motor Classification System (GMCS). Children with significant mental or psychological and/or visual/auditory problems; surgery

and/or Botox injection of the upper limb in the past 12 months or fixed deformities in the affected upper extremity were excluded.

Procedures for sample selection: The level of upper extremity manual ability was estimated by the MACS. It is a reliable and has been validated for children with CP age from 4 to 18 years. It classifies manual abilities in to five levels. Children at level I can easily and successfully handle objects, while those on level V - have significant impaired ability to carry out simple tasks [12].

The MASis a valid and reliable clinical tool used to assess the degree spasticity evaluation in CP that classifies muscle tone in 6 degrees (0, 1, 1+, 2, 3, 4) [13].

Motor function was estimated by the GMFCS according to the child's functional and walking capacity based on the chronological age. The GMFCS classifies the functional abilities in to one of five levels. Level I indicate the ability of walking with no limitations, meanwhile level V indicates significant impairments and need comprehensive physical aid [14].

Procedures for assessment

Assessment of selective motor control: Test of arm selective control (TASC), a valid and reliable tool, was used to measure selectivity of upper extremity of shoulder; elbow; wrist; fingers movements and thumb extension (key grip) as described in in the illustrated guide for administration and scoring. The assessments were carried out while sitting on a comfortable chair with his/her feet on the floor. The examiner demonstrated to the child the test requirements for the two main starting positions and joint movements. With the shoulder in mid rotation: 1) elbow, wrist, and fingers in extension; 2) 90º elbow flexion, forearm in mid position with the wrist and fingers in extension. For each movement, the examiner passively moved the tested upper extremity to assess the full range of motion and demonstrate the desired movement. Then, he/she was instructed to actively move the test upper extremity using a three-second verbal count. Each position was scored as unable (0); impaired (1) or intact SVMC (2) with total score for each upper extremity is 16 and 32 for both tested upper extremities [15].

Assessment of upper extremity function: The quality of upper extremity skill test (QUEST) is a reliable and valid tool used to measure the motor function in children with CP ages of 18 months to 8 years. The assessment procedures were conducted according to the instruction manual to assess the movement patterns in four basic domains representing dissociated movement; grasp; protective extension; and weight bearing. The total scores for each domain percentage score are calculated as total score which range from zero to 100% with higher score reflects better performance [5,16].

Assessment of grip strength: The hand held dynamometer (Patterson Medical, Warrenville, IL, USA) is a valid and reliable tool to assess grip strength in typically developing and disabled children recorded in kilogram [17]. The assessment was carried out with the child sitting on a chair with back support with suitable height to maintain the hips and knees at right angles and feet maintained on the supporting surface in neutral position. The tested upper extremity was aligned beside the body forearm and wrist in neutral positions with 90º elbow flexion. Then, each child was instructed to maximally compress the handle of the dynamometer. Each child conducted three trials and the mean was recorded in kilogram for statistical analysis [18].

Statistical analysis: Statistical package for social studies version 22 for windows (IBM SPSS, Chicago, IL, USA) was used and the level of significance was set at $p < 0.05$.Descriptive statistical analysis in the form of mean, standard deviation, minimum, maximum, frequency, median and interquartile range were conducted to present the data.Pearson Correlation Coefficient was used to investigate the correlation between TASC and QUEST and hand grip strength.

RESULTS

Subjects characteristics: Forty-eight children (25 girls and 23 boys) with mean ± SD age, weight, height and BMI were 6.05 ± 1.28 years, 21.55 ± 6.47 kilogram, 106.25 ± 12.74 centimeter, 18.75 ± 3.12 kg/m² respectively participated in this study. The mean ± SD of TASC and QUEST scores were 10.1 ± 2.37and 80.4 ± 12.57% respectively while the mean ± SD hand grip strength was 3.67 ± 2.06 kg. Participant's characteristics are presented in (Table 1).

The results showed positive significant correlation between TASC and QUEST (r = 0.85, p = 0.001); TASC and hand grip strength (r = 0.77, p = 0.001) and finally between the QUEST and hand grip strength scores (r = 0.72, p = 0.001) (Table 2).

Table **1**. Participant general characteristics:

	Mean ± SD	Maximum	Minimum
Age (years)	6.05 ± 1.28	8	4
Weight (kg)	21.55 ± 6.47	35	11
Height (cm)	106.25 ± 12.74	133	85
BMI (kg/m²)	18.75 ± 3.12	26	11.34
TASC score	10.1 ± 2.37	6	13
QUEST (%)	80.4 ± 12.57	35.17	95.8
Hand grip strength	3.67 ± 2.06	0.2	8
	Median	IQR	
MAS	1	2-1	
GMFCS	I	I-I	
MACS	I	I-I	
Sex distribution	N	%	
Girls	25	52	
Boys	23	48	
Affected side	N	%	
Right	26	54	
Left	22	46	

SD: Standard deviation IQR: interquartile range
GMFCS: Gross motor function classification system
MAC: Modified Ashworth Scale
MACS : Manual Ability Classification System
QUEST: Quality of upper extremity skill test
TASC: Test of arm selective control

Table 2. Correlation between selective motor control, upper limb function and hand grip strength

	TASC		QUEST	
	r - value	P- value	r - value	P- value
Hand grip strength	0.77	0.001	0.72	0.001
TASC	-	-	0.85	0.001
r value: Pearson correlation coefficient		p value: Probability value		
QUEST: Quality of upper extremity skill test		TASC: Test of arm selective control		

DISCUSSION

This study endeavored to investigate correlation between SVMC and upper extremity function in children with hemiparesis; as there is paucity in the literature regarding studies examined this relation between SVMC and upper extremity function in children with CP. The results of the current study showed positive correlation between SVMC, upper extremity function and hand grip strength in children with hemiparesis. These findings can be attributed to possible concepts. One concept is related to the primary upper motor neuron lesion (UMNL) signs including increased tonicity; reduced strength; lack of motor selectivity; abnormal muscle co-contraction and sensory-neural impairments. The second concept is the secondary musculoskeletal deformities and limited range of motion.

Functional performance requires highly coordinated skills to achieve complex movement of upper and lower extremities as grasp, reaching and walking. These skilled movements are influenced by integration of multiple systems including musculoskeletal, neuromuscular and vestibular systems. In children with CP, the UMNL is manifested by disruption of function of different body systems.

Upper limb and hand functions are complex and require regulation of several body systems) perception, muscle strength, motor control and intact visual and tactile sensation) that may be affected UMNL such as CP [19]. Functional performance is accomplished through intact motor cortex and descending neural connections that are responsible for appropriate motor activation and execution of movement. In children with CP, functional impairments are due to combination of multiple neural and motor defects. Among children with CP, spasticity and soft tissue contractures are considered the main causes for motor impairments; however, deficits in SVMC are the main contributor to that impairments [8].

Gross et al [20] stated that, in children with spastic CP, the relationships between the different symptoms of the UMNL; weakness, spasticity, muscle co-activation, loss of movement selectivity; and effective functional performance remain debatable. Functional impairments could be primarily due to lack of motor control or secondary to musculo-skeletal deformities. Previous studies reported that, UMNL is manifested by tone abnormalities, decreased muscle strength, functional impairments and loss of SVMC secondary to lesion of CSTs within the periventricular area. In patients with CP, damage to these tracts results in impaired SVMC [21,22].Lesion of CSTs disrupts the capability to control the movement force, speed, and timing sequence of muscle contractions that disturbs the isolated voluntary movements [23]. However, the patho-physiological mechanism of lack of SMC remains unclear. This could be due to persistence of the primitive flexor ⁄ extensor patterns, lack of connections to the CSTs, or due to both [24].

The results of the current study are supported by previous studiesstated that,functional limitations in children with CP are related to the flexor synergy in the upper extremity interferes with isolated joint movements and restricts agonist antagonist activation [25]. Impaired selectivity is a neuromuscular deficit occurs along with muscle weakness, spasticity, and short muscle–tendon length. These defects are associated with lesion to CSTs resulting in subsequent interruption of descending excitatory and inhibitory signals [26].

Smitherman et al. [27] and Rathinam et al. [28] reported that SVMC has a positive effect on upper extremity function in children with hemiparesis as grasp, bilateral hand use, reaching which is related with limited motor skills and in ability to perform regular daily activities.The results of the current study are supported by previous studies reported moderate to high correlations between upper limb function and hand grip strength. Moreover, it has been stated that, grip strength is a good predictor of hand functions [29-32].

Children with CP demonstrate mirror movements with uncontrolled simultaneous associated movements at contralateral joints. This sign is explained by timing errors of muscle recruitment. In other words, failure to selectively recruit a muscle or muscle group without inappropriate antagonist muscle activation resulting in a common neurological sign known as synergies. This sign is directly related to lesion of CTRs and loss of SVMC [33].

CONCLUSION

Based on the results of the current study it can be concluded that, functional impairments in children with CP is multifactorial. Both lack of SVMC and muscle weakness are main contributors to functional limitations of upper extremity in children with hemiparesis.

Limitations: The sample was delimited to children with hemiparesis. Second, there is limited literature on the relation between SVMC and upper extremity function in children with CP.

Recommendations: Future researches on larger sample and different types of CP are recommended. Moreover, multidimensional analysis using objective assessment tools are recommended to validate the relation between SVMC and muscle strength. Multidimensional assessment of musculoskeletal factors as rang of motion; contractures and spasticity are recommended to analyze possible factors related to functional impairments among this population.

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