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Cortical Sensations and Fine Motor Skills in Children with Spastic Hemiplegic Cerebral Palsy

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Abstract:
Background: *Hemiplegic cerebral palsy (HCP) results from damage to the cortico-spinal tract and other developing pathways resulting into impaired hand dexterity, leading to developmental nonuse affecting daily self-care activities and school activities. According to motor control, sensations modulate the movement. Impaired sensations negatively impact on acquisition of skilled movement.*
Aim: *To determine the relation between cortical sensations and fine motor skills in children with spastic hemiplegic cerebral palsy.*
Design: *Cross-sectional study.*
Settings: *Outpatient clinic, Faculty of Physical Therapy, Cairo University.*
Participants: *Forty children (17 girls and 23 boys) with spastic HCP, aged from 6 to 13years.*
Outcome measures: *Cortical sensations (stereognosis and tactile localization)were assessed by NotinghamSensory Assessment Scale (NSA) and fine motor skills (grasp and visual motor integration) were assessed by Peabody Developmental Motor Scale (PDMS-2).*
Results: *There was statistically significant correlation between stereognosis and fine motor skills and between tactile localization and fine motor skills in children with spastic HCP (P<0.05).*
Conclusions: *There was a significant correlation between cortical sensations and fine motor skills in children with spastic HCP. Thus, cortical sensations should be assessed in children with fine motor skill problems.*
Key words: *Cerebral palsy, Cortical sensations, Fine motor skills,Hemiplegia, Stereognosis.*

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I. Introduction

Cerebral palsy (CP) is a permanent and nonprogressive condition that impacts posture and movement, affecting 2.0– 3.5 per 1,000 live births[1].Insults to different areas within the developing nervous system, which partially explains the variability of clinical findings as spasticity, dystonia, ataxia, hypotonia and dyskinesia. According to patterns of motor involvement, spasticity can be represented in the form of hemiplegia, diaplegia, triplegia or quadriplegia**[2].**

Hemiplegic cerebral palsy (HCP) is a subtype in which one side of the body is involved. It affects about 1 in 1,300 live births [3]. Hemiplegic cerebral palsy (HCP) is caused predominantly by unilateral damage of the developing brain which leads to unilateral, asymmetric muscle tone abnormalities and deformities**[4].**

Cortical sensations are developmental sensation which has occurred due to the learning and integration function of the brain. They are controlled by the sensory cortex and don't have a separate peripheral representation like receptors or the nerve ending. They are learned form of tactile sensation so they mediated by the same receptors. They comprise of tactile localization, two point discrimination, graphethesia, barognosia and stereognosis. Tactile localization is the ability of person to exactly point the area that is either picked or touched by therapist. Stereognosis is the ability of person to recognize familiar object with the help of tactile sensation **[5].**

Fine motor skills are the use of small muscles involved in movements that require the functioning of the extremities to manipulate objects [6]. These skills play a role in many activities of daily life such as dressing and feeding one's self, in addition to being essential in writing and drawing**[7].** They include grasp, reach, carry, voluntary release, in hand manipulation and bilateral hand use **[8].**

In children with HCP, upper limb function depends on several factors including the severity of paresis, the degree of spasticity and the extent of sensory loss [9]. Sensory deficit is typically classified as lack of normal development of the somatosensory system and can result in deficits in identification of different forms of sensory modalities such as touch, the ability to detect position in space and the ability to use the hand to identify objects (haptics).Tactile impairments present in children with HCP according to Auld et al. as follow; 40% of children with HCP have registration and perception deficits, an additional 37% have tactile perception deficits and 23% of children with HCP do not have a tactile impairment**[10].**

Children with HCP commonly exhibit sensory deficiencies in their hands in addition to motor problems**[11]**. They exhibit various types of sensory processing deficits from which mostly identified sensory deficits include astereognosis, impaired two point discrimination and difficulty with position sense which majorly relate to tactile processing. Tactile processing disorders are tactile modulation deficits; hypo responsiveness to tactile input or registration deficits and tactile discrimination deficits; inability to identify the temporal and spatial qualities of tactile stimuli **[12].**

The sensory abilities and especially the sensorimotor integration of children with HCP are affected and do have an influence on precision grip. With a better sensorimotor integration (due to many trials or inputs from the less-affected hand), anticipatory control of precision grip is improved. This leads to the question of the training not directly of the sensory abilities, but more of the sensorimotor integration in neurorehabilitation for these patients**[13].**

Recent studies have begun to examine impairments in tactile registration and perception [14] and their potential impact on unimanual capacity **[15]**and bimanual performance**[16].**In recent years, specific tactile deficits, such as spatial tactile discrimination, texture perception, and object recognition have been identified in children with dystonia**[17]** and diplegia**[18].**Although information is increasing, systematic analysis of how tactile and motor deficits interact in children with HCP is lacking. Therefore, the aim of this study was to investigate the relation between cortical sensations and fine motor skills in children with spastic HCP. It was hypothesized that there would be significant relationships between them.

II. Methods

2.1. Study Design

This study was a cross-sectional on 40 children with HCP aged from 6 to 13 years. Ethical committee approval of the Faculty of Physical Therapy, Cairo University as well as a written consent from children‘s parents were obtained before starting the study.

2.2. Participants

Children from both sexes were eligible to be enrolled if they had a confirmed diagnosis of HCP, had spasticity ranged from grade1 to 2 according to Modified Ashworth Scale, were able to understand and follow instructions, had cortical sensations affection (tactile localization and stereognosis) and were able to grasp an object by the affected hand.

Exclusion criteria: Children were excluded from this study if they hadupper-limb botulinum toxin injections 3 months prior to recruitment in this study, previous upper-limb orthopedic surgery, fixed upper limb deformities and auditory or visual impairment.

2.3. Outcome measures:

2.3.1. Cortical sensations:

Stereognosis and tactile localization were assessed usingNotingham Sensory Assessment scale (NSA).Notingham Sensory Assessment scale was first developed by Lincoln et al. **[19]**as sensory assessment tool for physiotherapists and included assessments that were commonly used in clinical practice, but in a more standardized format. It includes tests of light touch (applied using cotton wool), pressure (applied using the assessor‘s finger), pinprick (using a neurotip), and temperature (using hot and cold water in test tubes). It also assesses tactile localization, bilateral simultaneous touch, proprioception, two-point discrimination and stereognosis. Notingham Sensory Assessment scale was found to have good intra-rater reliability but poor inter-rater reliability and was a lengthy assessment. This led to revisions of the NSA, shortening the scale and producing a hierarchy of items**[19].**

2.3.2. Fine motor skills:

Grasping and visual motor integration were assessed using Peabody Developmental Motor Scale (PDMS-2). It is an early childhood motor development program that provides (in one package) both in depth assessment and training of gross and fine motor skills. Reliability and validity have been determined empirically. This scale provides a comprehensive sequence of gross and fine motor skills, from which the therapist can determine the relative developmental skill level of a child, identify the skills that are not completely developed and plan an instructional program to develop those skills. It is composed of six subtests:

Reflexes (8items), stationary (30items), locomotion (89items), object manipulation (24items), grasping (25items) and visual motor integration (72items) **[20].**

2.4. Procedures
2.4.1. Assessment of cortical sensations
2.4.1.1. Stereognosis.
Preparation:

1-Participants sat on comfortable chair according to their age.
2-Any accessories like (rings and watches) were removed from the hand so as not to hinder the object manipulation in the hand.
3-Stereognostic tools were presented in front of the child. The eleven objects were demonstrated to the child to ensure that he knows them.

Testing:

1- Each child tried to identify eleven familiar objects (2p coin, 10p coin, 50p coin, biro (score 2 if labelled "pen"), pencil, comb, scissors, sponge, flannel (score 2 if labelled "cloth" or "face cloth"), cup, glass (score 2 if labelled "beaker").
2- Each object was placed in the child‘s hand while he/she blind folded for a maximum of 30 seconds. Identification was by naming, description or by pair-matching with an identical set.
3- The object might be moved around the affected hand by the examiner.

Scoring:
The score was the sum of correct responses out of a possible maximum of 22.

2.4.1.2. Tactile localization.
Preparation:

The patient should be assessed in sitting position wearing suitable clothes. It should be ensured the patient was comfortable and in a quiet area with no distractions. Each test was described and demonstrated to the patient before he or she was blindfolded. The blindfold was removed regularly throughout the test to avoid the patient becoming disorientated.

Testing:

1- The test sensation was applied to the test areas of the wrist and the hand. The blindfolded patient was asked to indicate, either verbally or by a body movement, whenever he or she felt the test sensation. Each area was assessed three times. Presence of a reflex did not count as awareness of sensation, though this should be commented on in the comment box.
2- Only those areas on which the patient has scored 2 on the pressure section were tested.
3- The pressure test with the index fingertip coated with talcum powder to mark the spot touched, was repeated and the patient was asked to point to the exact spot that has been touched.
4- When communication permitted, the test of tactile localization was combined with the pressure test. Two cm of error were allowed.

Scoring:

Wrist and hand regions were tested, maximum score for each one was 2 and for both were 4. The score was the sum of correct responses out of a possible maximum of 4.

2.4.2. Assessment of fine motor skills
Preparation:

Each child sat on a chair-table that permits him or her to comfortably place feet on the floor. The table was large enough to allow the examiner and the child to sit opposite to each other or side by side. Also, the table accommodated the manipulative materials and the examiner record booklet.

Testing and scoring:

Grasping and visual motor integration, subtests of PDMS-2, were assessed usingthe entry points, basal and ceilings to shorten testing time. After administration of all items in each subtest (grasping and visual motor integration), raw and standard scores were calculated for each one. Finally, fine motor quotient was determined.

III. Statistical Analysis

Data were statistically described in terms of mean ± standard deviation (± SD), median and range, or frequencies (number of cases) and percentages when appropriate. Normality of numerical data was tested using Kolmogorov Smirnov test. Correlation between various variables was done using Pearson moment correlation equation for linear relation of normally distributed variables and Spearman rank correlation equation for non-normal variables/non-linear monotonic relation. *P* values less than 0.05 was considered statistically significant. All statistical calculations were done using computer program IBM SPSS (Statistical Package for the Social Science; IBM Corp, SPSS (Statistical Package for the Social Science; IBM Corp, Armonk, NY, USA) release 22 for Microsoft Windows.

IV. Results

1. Results of demographic data:

Table (1) reveals mean, standard deviation, minimum, maximum and median of age, stereognosis, tactile localization, fine motor quotient,grasp standard score and visual motor integration standard score. Frequency and percentage of sex, affected side and spasticity grade were also calculated as shown in Table (2).

Table (1): Demographic data of the participants

	Age	**FMQ**	**Stereognosis**	**TL**	**Grasp score**	**VMI score**
Mean+_SD	7.70±1.911	59.35±15.175	13.85±3.355	2.23±0.620	3.53±2.891	2.93±2.422
Minimum	6	46	6	1	1	1
Maximum	13	100	21	3	9	11
Median	7.00	55.00	15.00	2.00	2.50	2.00

SD: Standard deviation, FMQ: fine motor quotient, TL: tactile localization, VMI: visual motor integration.

Table (2): Frequency and percentage of sex, spasticity and affected side

Item	**Frequency**	**Percentage**
Sex		
Girls	17	42.5
Boys	23	57.5
Spasticity		
Grade 1	11	27.5
Grade 1+	19	47.5
Grade 2	10	25.0
Affected side		
Right	18	45.0
Left	22	55.0

2. The correlation between stereognosis and fine motor skills:

As shown in Table (3) and Fig (1, 2, 3), there was significant correlation between stereognosis and fine motor quotient (r= 0.630; P <0.05).Significant correlation was found between stereognosis and grasp standard score (r=0.649 ; p <0.05) and also between stereognosis and visual motor integration standard score (r=0.630 ; p <0.05).

Table (3): Correlation between stereognosis and fine motor skills

Correlation	**r**	**P**	**S**
Stereognosis-FMQ	0.630	0.000	S
Stereognosis-grasp standard score	0.649	0.000	S
Stereognosis-VMI standard score	0.630	0.000	S

r: Pearson and Spearman correlation coefficient, P: probability, S:significance, FMQ: fine motor quotient, VMI: visual motor integration

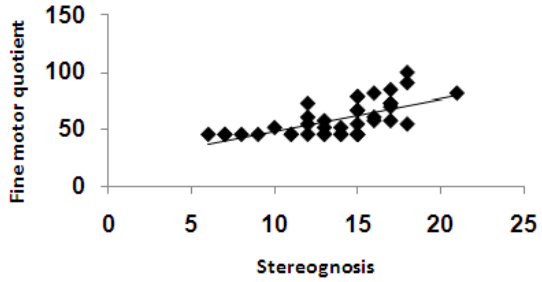

Figure (1): Correlation between stereognosis and fine motor quotient of the study sample

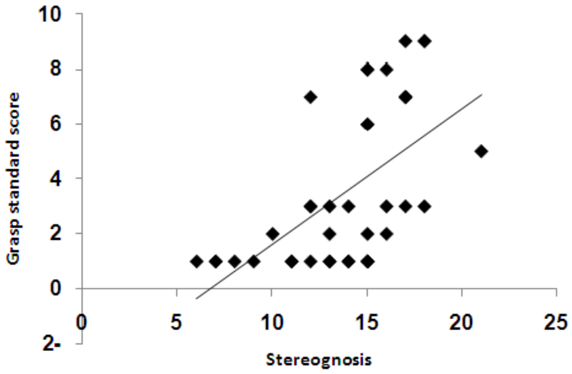

Figure (2): Correlation between stereognosis and grasp standard score of the study sample

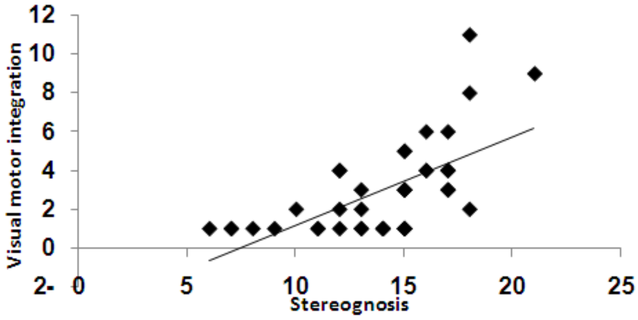

Figure (3): Correlation between stereognosis and visual motor integration standard score of the study sample

3.The correlation between tactile localization and fine motor skills:

As shown in Table (4) and Fig(4, 5, 6), there was significant correlation between tactile localization and fine motor quotient (r=0.359 ; P <0.05).Significant correlation was found between tactile localization and grasp standard score (r=0.321 ; p< 0.05) and also between tactile localization and visual motor integration standard score (r=0.389 ; p <0.05).

Table (4): Correlation between tactile localization and fine motor skills

Correlation	r	P	S
TL-FMQ	0.359	0.023	S
TL-grasp standard score	0.321	0.044	S
TL-VMI standard score	0.389	0.013	S

r: Spearman correlation coefficient, P: probability, S:significance, FMQ: fine motor quotient, VMI: visual motor integration, TL: tactile localization

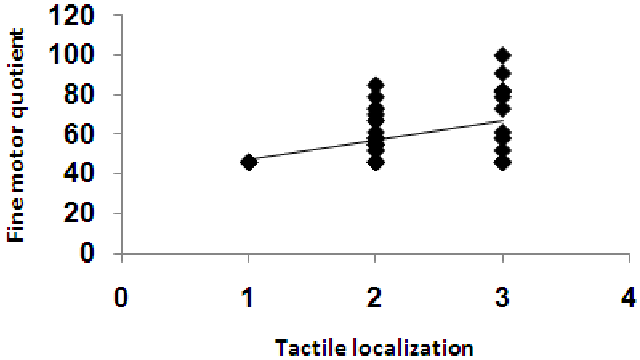

Figure (4): Correlation between tactile localization and fine motor quotient of the study sample

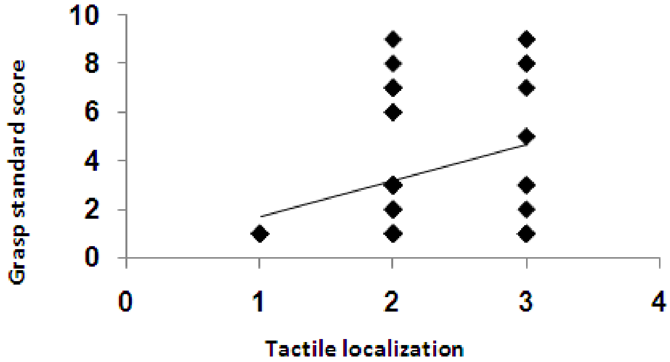

Figure (5): Correlation between tactile localization and grasp standard score of the study sample

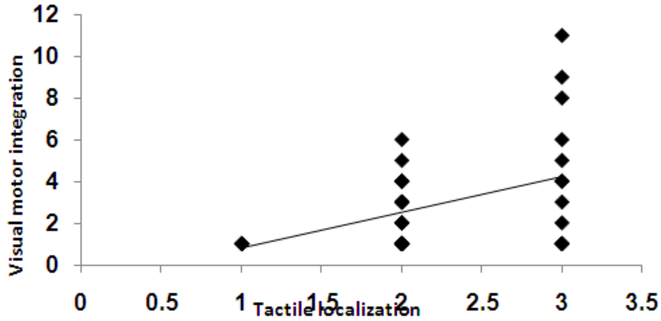

Figure (6): Correlation between tactile localization and visual motor integration standard score of the study sample

V. Discussion

The results of this study indicated that there was positive significant correlation between cortical sensations (stereognosis and tactile localization) and fine motor skills in children with spastic HCP. These results are supported by findings from previous studies indicating that tactile function is compromised in CP**[11, 18].**

Both cortical sensations (stereognosis and tactile localization) and fine motor skills (grasping and visual motor integration) were assessed using NSA and PDMS-2. Stereognosis and tactile localization were chosen to be assessed from all types of cortical sensations as **Raj [5]** reported that from practical point of view testing the tactile localization and stereognosis is sufficient for assessing one‘s cortical sensation abilities.

Carlson and Brooks[21]considered stereognosis as a complex interaction between sensory input, motor control and the brain’s ability to integrate this information. In children with spastic HCP, motor control of the upper limb is affected. Upper limb takes the hemiplegic pattern and the wrist joint remains flexedduring grasping an object.The flexion contracture of the wrist weakens and makes grasping very difficult. This is due to the flexor muscles of the wrist, particularly the flexor carpi ulnaris, remaining contracted during finger flexion (co-contraction). The flexion of the wrist slackens the long flexors and hence weakens the grip. It also causes difficulty in stabilizing the wrist in extension to allow the hand to grasp effectively. This alters the normal pattern of grasp of the hand. The thumb which held flexed inside the palm impairs hand grip and obstructs the function of other fingers and also the lack of abduction and extension limits the size of the object that the child can grasp **[22]**. Therefore, stereonosis could be affected in HCP because of motor affection.

The results of the current study can be explained by the notion that action and perception are closely linked, that they probably share common neural correlates in the cortex and that they therefore, cannot be divided into discrete functional compartments**[23].Bleyenheuft and Gordon**[13] reported that the close interaction of motor and sensory systems can make it challenging to determine their relative contribution to functional impairments in HCP.

The findings of this study indicated significant relationships between cortical sensations (tactile localization and stereognosis) and fine motor skills (grasping and visual motor integration). This means if a child has difficulty identifying the location or spatial characteristics of a tactile stimulus, this difficulty will be related to his/her deficits in upper-limb fine motor function. This is consistent with the many spatial aspects to planning, executing, and processing feedback for movement and concurs with the views of **Arnould et al. [24]** on the role of testing tactile spatial resolution.

The results of the present study can also be supported by previous findings of **Sakzewski et al. [16]**who studied the relation between unimanual capacity and bimanual performance in children with congenital hemiplegia. Their results not only support the presence of a relationship between tactile function and manual capacity, but also indicate that fine force control and proprioceptive feedback, as required for stereognosis, may be crucial for manual performance.

For successful grasping an object, the finger movements should be timed appropriately. If they close too early or too late the grasp will be inappropriate. The ability to grasp it precisely between the thumb and index finger requires close interplay between the sensory inputs from the fingers and mechanisms controlling the motor output of hand and finger muscles. This precision grasp and manipulation depends on sensory tactile information which conveys information regarding object texture, shape, size in the development of internal representation about an objects characteristic. During lifts, internal representations of the object are used to preprogram grip lift task forces. Thus, scaling of forces is performed prior to the lift and it is dependent on both sensory motor memory representation and current tactile information. Impaired sensibility would probably not provide enough sensory information to form vivid internal representation of objects physical properties**[25].**

The results of the current study also matches with the results of **Elliasson et al.[26]**who found impaired tactile regulation of isometric fingertip forces during grasping in hemiplegic children. They suggested that children with cerebral palsy who have sensory impairments may not be able to extract enough information during initial manipulatory experiences to form internal representations of the object properties. **Gorden and Duff [27]**reported that learning to use anticipatory control of load forces was based on texture, weight of an object.

The findings of this study come in agree with **Johansson et al.[28]**who stated that tactile information is used to monitor the weight of an object (vertical lifting force and the frictional characteristics of the object)in relation to slip enabling the motor output. Depending on the notion that during manipulation, brain quickly extracts information from discrete tactile events and expresses this information in fingertip actions faster.

Auld et al. [10] studied the correlation betweentactile function and upper limb function in 52 children with spastic HCP. They assessed tactile registeration, spatial perception and texture perception and used twounimanual tests, the Melbourne Unilateral Upper Limb Assessment (MUUL) and Jebsen-Taylor Test of Hand Function (JTTHF) and one bimanual test, the Assisting Hand Assessment (AHA)for the upper limb function. They found that stereognosis followed by single point localization showed the strongest relationships with unimanual capacity on the MUUL. Single point localization also showed the strongest relationship with unimanual speed and dexterity on the JTTHF. Stereognosis and double simultaneous showed the strongest relationships with bimanual performance on the AHA.

Byl [29] described a program aimed to improve accuracy and speed in sensory discrimination and sensorimotor feedback. Improvements in sensory discrimination, fine motor function and musculoskeletal measurements of the upper limb were reported following sensorimotor training; however, they also suggested that it was not possible to determine the effectiveness of sensory training alone.

Salkar et al. [12]studied the effect of tactile stimulation on dexterity and manual ability of hand in HCP children. They used conventional rehabilitation program and tactile stimulation exercises like texture, shape, size, common object identification, touch stimulation and localization with eyes open and closed. Three sessions per week for six weeks of intervention protocol was followed. They found significant improvement in dexterity and manual ability after treatment.These results indicated that stereognosis and tactile localization showed a relation with fine motor skills in HCP children.

VI. Conclusions

It can be concluded that cortical sensations are significantly correlated with fine motor skills in children with spastic HCP. Therefore cortical sensations assessment and training should be considered in the rehabilitation of the upper limb in children with spastic HCP.

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Conflicts of interest

No potential conflict of interest relevant to this study was reported.

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