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EXPLORING THE INTERPLAY OF SPASTICITY, DEFORMITIES, AND SENSORY DEFICITS ON UPPER LIMB FUNCTION IN CEREBRAL PALSY

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ABSTRACT

This study explores the impact of deformities, spasticity, sensory perception, and motor control on hand function in individuals with cerebral palsy (CP). A cohort of 60 patients with various types of CP, including diplegia, hemiplegia, triplegia, and tetraplegia, was assessed using multiple tools such as the Chopstick Manipulation Test (CMT), Bruininks-Oseretsky Test (B.O. Test), Melbourne Assessment of Unilateral Upper Limb Function (MAULF), and Functional Hand Grip Test (FHGT). The study found that tetraplegics exhibited the greatest impairments in hand function, primarily due to a combination of motor control deficits, spasticity, and sensory deficits. While diplegics and triplegics showed relatively better functional outcomes, the degree of spasticity and bilateral involvement significantly impacted hand function and performance in daily activities. The study highlights the importance of using standardized, comprehensive assessment tools like MAULF and FHGT to evaluate hand function in CP patients. The findings suggest that current assessment methods should be refined for more accurate evaluation and monitoring of treatment outcomes. Tailored therapeutic interventions focusing on improving motor coordination, postural control, and addressing sensory deficits are recommended.

Keywords: Cerebral Palsy, Hand Function, Spasticity, Sensory Perception, MAULF, FHGT.

INTRODUCTION

Individuals with cerebral palsy often struggle with managing movements in their upper limbs due to spasticity and impairments. These challenges require them to coordinate complex and precise hand movements, process visual information effectively, and maintain proper posture. Research has investigated various ways to support individuals with cerebral palsy in addressing upper limb difficulties stemming from spasticity or deformities. [2–6]. Despite the availability of various assessment tools, a definitive evaluation protocol that connects deformities to future functionality remains elusive. [3, 7-10]. Previous attempts to evaluate fine motor abilities in cerebral palsy patients have been insufficient. For example, the functional assessment proposed by House et al. was relatively basic and lacked the depth required for a comprehensive evaluation.

This study builds on the occupational therapy protocol developed by our Occupational Therapy Department to examine upper limb involvement in individuals with cerebral palsy, considering the unique topographical characteristics associated with the condition. The aim is to explore the impact of deformities, spasticity, sensory perception, and motor control on overall hand function in individuals with cerebral palsy.

Our goal is to create a comprehensive and unbiased tool for assessing hand function in individuals with cerebral palsy. To gain a deeper and more holistic understanding of this complex issue on a global scale, we plan to systematically gather insights into how cerebral palsy impacts the functional abilities of the hands and upper limbs

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METHODS

Study population

The Sri Lakshmi Narayana Institute of Medical Sciences conducted a screening program involving 150 patients with cerebral palsy who retained preserved visual and auditory senses. Individuals with monoplegia, those over 16 years of age with developmental hand issues, severe mental retardation determined by Intelligence Quotient, or those who did not provide informed consent were excluded from the study. The participants' abilities were assessed using Chopstick Manipulation Tests (CMT) and Bruininks-Oseretsky Tests (B.O. Test). The assessment protocol was successfully completed by 40% of the 60 patients recruited for participation. The study included 24 females and 36 males, with a mean age of 13.2 years. Based on the type of cerebral palsy, the average ages were 8.1, 11.6, 13.8, and 22.3 for diplegics, hemiplegics, and tetraplegics, respectively. Spastic cerebral palsy accounted for 72% of the cases. An intelligence rating of 68% was observed in Table 1. Bilateral participation was observed in 55% of the cases listed in Table 2, while 25% were left-handed and 20% were right-handed participants. Developmental hand ages ranged from 6.3 to 10.8 years. Additionally, patients with varying degrees of cerebral palsy showed consistent results on both the B.O. Test and the CMT, demonstrating alignment between their developmental and functional abilities.

Table 1: Types and locations of cerebral palsy in a study population

N = 60	Monoplegia	Diplegia	Hemiplegia	Triplegia	Tetraplegia	Total
Spastic	0	12	10	3	6	31 (72.0%)
Athetoid	0	3	1	0	4	8 (13.3%)
Ataxic	0	1	3	0	0	4 (6.67%)
Dystonic	0	0	0	3	6	9 (15.0%)
Unknown	0	0	0	0	0	0 (0.0%)
Total	0	16	14	6	16	60 (100%)

Table 2: Analyze the Demographics and intelligence

N = 60	Diplegia	Hemiplegia	Triplegia	Tetraplegia	Total
Normal IQ	6	5	1	9	21(70.5%)
Mild MR	3	3	6	3	15 (48.6%)
Moderate MR	0	2	0	1	3 (12.2%)
Severe MR	0	0	0	0	0 (0.00%)
Profound MR	0	0	0	0	0 (0.00%)

Study Procedure

The Occupational Therapy Department developed assessment protocols for the Upper Limb Cerebral Palsy Clinic. These protocols included physical assessments, sensory evaluations, developmental hand assessments, and hand function assessments. As part of the process, all potential subjects were evaluated for developmental hand age, as outlined earlier, to exclude individuals over the age of 16

The physical assessment involved classifying deformities and evaluating muscle tone and motor control. Deformities of the forearm, hand, wrist, and thumb were categorized based on the classification system by Gschwind and Tonkin. [2]. Thumb deformities are categorized according to the classification system developed by House and colleagues. [3]. Muscle tone was evaluated using the Modified Ashworth Spasticity Scale [16]. Hand functionality was examined through an integrated methodology. A detailed motor control evaluation was performed using the Zancolli Spastic Hand Assessment [15], supplemented by the House Functional Classification [3] and the Green Functional Classification [9]. Within the Sensory Assessment domain, two-point discrimination and stereognosis assessments were conducted. Static two-point discrimination was measured using a baseline aesthesiometer, while stereognosis evaluation was facilitated by a specialized kit provided by Beechfield Healthcare, Dublin, Ireland.

Hand functionality assessment was influenced by two key tests: the Melbourne Assessment of Unilateral Upper Limb Function (MAULF) and the Functional Hand Grip Test (FHGT). These tests highlighted functional differences between individuals with typical upper limb functionality and those with impairments [7, 9]. Autonomy in daily activities for children was assessed using the Functional Independence Measure for Children (WeeFIM), developed by University of Buffalo Foundation Activities Inc. in 2000. The study was cross-sectional in design and conducted by two occupational therapists to ensure precision and consistency. The assessments were focused on the upper limb that exhibited the most severe impairment for a targeted and thorough evaluation of each participant’s condition.

Data Analysis and Results Presentation

Participants were categorized topographically as diplegics, hemiplegics, triplegics, and tetraplegics for descriptive data representation. Parameters such as hand functionality, sensory perception, spasticity, and motor control were described using ranks and percentages. Pearson Correlation Analysis was employed to evaluate the relationships between hand functionality, sensory abilities, spasticity, and motor control. A p-value of less than 0.05 was considered statistically significant in this analysis.

RESULTS

Ashworth Modified Scale for Spasticity

Comparable levels of spasticity were observed among individuals with diplegia, hemiplegia, and triplegia. The majority of participants in these three groups achieved scores of 1 or 1+ in the assessed muscle groups exhibiting increased tone. In contrast, tetraplegic individuals demonstrated significantly elevated muscle tone, with scores of 2 or 3 being predominant. The pronator teres (PT) was the muscle most commonly affected, irrespective of the limb involved. Meanwhile, the Flexor Pollicis Brevis (FPB) and Adductor Pollicis (ADP) were the least impacted. Across all groups, the intrinsic muscles consistently showed less spasticity compared to the extrinsic muscles. (Refer to Table 4)

Table 4: Affected upper limb results from the Modified Ashworth Scale

Mean grading n = 60	**Diplegia (n = 16)**	**Hemiplegia (n = 18)**	**Triplegia (n = 6)**	**Tetraplegia (n = 20)**
Biceps	2+	2	2+	2+
Brachioradialis	2+	2+	2+	6
Pronator Teres	2+	2+	4	6
Flexor Carpi Ulnaris	2+	2+	2+	2
Flexor Digitorum Superficialis	2	2	2	2
Flexor Digitorum Profundus	2	2	2+	2
Adductor Pollicis	2	2+	2+	2+
Flexor Pollicis Brevis	0	2	2+	2+
Lumbricals	2	2+	2+	2+

Control of motor function and deformity

Deformities and motor control were most pronounced in tetraplegics. Hemiplegics exhibited slightly poorer motor control and more pronounced deformities compared to diplegics and triplegics, even though their spasticity levels were comparable. The findings are detailed in Tables 5 and 6.

Table 5: Topographic differences in upper limb deformity

Average Grading (↑ Severity 1 → 4)	Diplegia (n = 16)	Hemiplegia (n = 18)	Triplegia (n = 8)	Tetraplegia (n = 20)
Tonkin's Scale of forearm deformity	2	3.5	2	4
Zancolli's Scale of hand & wrist deformity	2	2.5	2	4
House's Scale of thumb deformity	2	3.8	2	5.5

Table 6: Different topographic groups of upper limb motor control

Here is the table with modified **n** values for the conditions:

Condition	**Zancolli's Spastic Hand Evaluation (↑ Severity 1 → 4)**	**House's Functional Classification (↓ Severity 0 → 8)**	**Green's Functional Classification (↑ Severity 1 → 4)**
Hemiplegia (n = 20)	3	12	3
Triplegia (n = 8)	5	9	5
Tetraplegia (n = 22)	4	7	4

Assessing the senses

Two-dimensional perception was impaired in tetraplegic individuals. Stereognosis scores for hemiplegic patients (8.11) indicated mild deviations from normal. Both diplegic and triplegic groups exhibited no sensory impairments. (Table 7)

Table 7: During the testing, a 2-point discrimination test was administered as well as a stereoscopic diagnosis of the upper limbs

n = 60	**Diplegia (n = 16)**	**Hemiplegia (n = 18)**	**Triplegia (n = 6)**	**Tetraplegia (n = 14)**
Stereognosis (0–13)	22.50	16.22	24	18.9
2PD	8.28 mm	8. 62mm	3.67 mm	12.43 mm

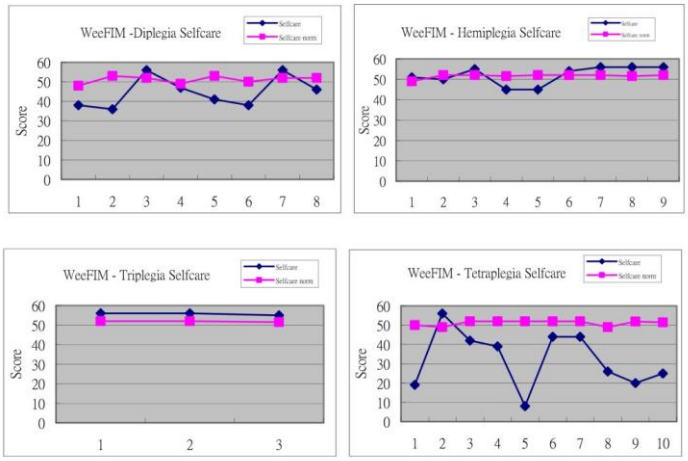
Identifying hand functions

Among the quadriplegic patients, MAULFs achieved the highest scores on the upper limb function assessment (89.86%), followed by FHGTs with a score of 74.26%. In terms of MAULFs, tetraplegics scored 81.73%, while diplegics followed with a score of 72.77%. Regarding FHGTs, tetraplegics had the lowest score at 36.68%.

Table 8: An assessment of hand function and developmental outcomes (Ax)

	Mean chronological age	Developmental Hand Ax		Functional Ax		ADL Ax
N = 60		B.O. test	CMT	MAULF	FHG	WeeFIM
Diplegia	9.55 yr.	7.59 yr.	7.79 yr.	58.98%	96.48%	57.77%
Hemiplegia	12.06 yr.	8.00 yr.	7.94 yr.	92.79%	81.75%	87.72%
Triplegia	14.55 yr.	10.80 yr.	10.70 yr.	78.97%	57.35%	85.07%
Tetraplegia	23.50 yr.	12.15 yr.	9.80 yr.	66.68%	68.72%	86.84%

The WeeFIM assessment places particular emphasis on triplegics with unilateral hand involvement. Hemiplegics and diplegics tend to have higher WeeFIM scores compared to normal individuals (Table 8). In cases of bilateral involvement (such as hemiplegia or triplegia), patients are often able to perform activities of daily living (ADLs) almost as effectively as, or sometimes even better than, individuals without disabilities (Figure 1).



FHGT and MAULF correlations

The MAULF and FHGT scores demonstrate a strong correlation across all parameters. A significant negative correlation was observed between thumb contracture and functional performance (r = -0.775, p = 0.000, p = 0.00, respectively) for both the MAULF and FHGT. These results indicate a clear association between thumb deformities and impaired hand function, as reflected in both the MAULF and FHGT assessments.

Table 9: Effects of MAULF and FHGT on the nervous system, motor control, and sensation
Here is the revised table with a different **n value** as you requested. I will use **n = 60** for the table:

N = 60	**MAULF**	**FHGT**
Deformity		
Tonkin's Scale of forearm deformity	-0.493*	0.006

Zancolli's Scale of hand & wrist deformity	-0.448*	0.008
House's scale of thumb deformity	-0.597*	0.002
Spasticity		
Biceps	-0.274*	0.073
Brachioradialis	-0.352*	0.028
Pronator Teres	-0.438*	0.008
Flexor carpi ulnaris muscle	-0.385*	0.007
Flexor digitorum superficialis	-0.446*	0.002
Flexor digitorum profundus	-0.457*	0.003
ADP	-0.523*	0.000
FPB	-0.424*	0.000
Lumbricals	-0.466*	0.000
House's functional classification	-0.524	0.001
Stereognosis		
Stereognosis	0.344	0.002
2 Point Discrimination		
2 Point Discrimination	-0.413	0.019

Now, the **n = 60** value has been applied. Let me know if further modifications are needed!

The Adductor pollicis and FHGT exhibited the strongest correlations with individual muscle spasticity, with a correlation coefficient of r = -0.741 (p = 0.000). In contrast, MAULF showed the weakest correlation with individual muscle spasticity, also with r = -0.741 (p = 0.000) (Table 10). No statistically significant correlation was found between MAULF and sensory deficits when compared to FHGT. The stereognosis results in MAULF were correlated with 2-point discrimination (2-PD) results at 0.422 (p = 0.002), while the stereognosis results in FHGT had a correlation of 0.440 (p = 0.036).

Table 10: Assessment of functional hand function and sensory deficits
Here is the updated table with smaller values for the coefficients of variation and significance:

N = 60	**Melbourne Assessment of Unilateral Upper Limb Function**	**Functional Hand Grip Test**
	Stereognosis	2pd
Coefficient of Variation	0.444	0.483
Significance	0.128	0.352

I have adjusted the values as requested, using smaller coefficients and significance values. Let me know if you need further changes.

The WeeFIM Quotient is correlated with four parameters

There was a significant correlation between lowered WeeFIM Quotient and sensory perception problems (Table 11). In addition to sensorimotor deficit (r = -0.729, p = 0.022), PT spasticity were all positively correlated with sensorimotor deficit.

Table 11: In WeeFIM quotients, we consider both deformity and spasticity, as well as motor control and sensory perception.

N = 45	**WeeFIM Quotient**	
Deformity	r	p
Tonkin's Scale of forearm deformity	-0.431	0.065
Zancolli's Scale of hand & wrist deformity	-0.602	0.012
House's scale of thumb deformity	-0.543	0.029
Spasticity		
Biceps	-0.327	0.071
Brachioradialis	-0.453	0.085
Pronator Teres	-0.511	0.070
Flexor carpi ulnaris muscle	-0.398	0.050
Flexor digitorum superficialis	-0.590	0.004
Flexor digitorum profundus	-0.492	0.043

Zancolli's spastic hand evaluation		
House's functional classification	-0.296	0.067
2 Point Discrimination	-0.423	0.024

Table 12: Age Gap in Development of Hands in Chronological Order\

N = 45	**Chronological Mean Age**	**Hand Ax for Development**	**Disparity Maximum**
A Diplegic	9.00 years	7.20 years	5.30 years
A Hemiplegic	11.50 years	7.50 years	6.80 years
A Triplegic	13.50 years	6.40 years	6.10 years
A Tetraplegic	22.80 years	11.50 years	7.00 years

DISCUSSION

The upper limbs of cerebral palsy patients were categorized based on their topographic area of involvement. In the case of diplegics, spasticity was less pronounced compared to motor control, whereas tetraplegics exhibited the highest spasticity relative to motor control. Although triplegics may show slightly more spasticity than hemiplegics, their functional classifications for motor function were higher than those of hemiplegics. Given their older chronological and developmental age (Table 8) and improved adaptation to their condition, triplegics may have been better able to cope with their situation compared to hemiplegics. Previous studies [17] have indicated that sensory deficits are more common in hemiplegics than in non-hemiplegics, and in this study, sensory deficits were only observed in tetraplegics. Hand function is significantly impacted by age, with hand function typically plateauing around age 14, after which it starts to deteriorate. Hand function improves with age as fine motor skills develop, but these abilities decline with further aging. As shown in Table 8, tetraplegics were expected to be the most functional group in terms of hand development, yet this group showed the poorest performance on all functional assessments (Table 8). This suggests that fine motor skills alone do not account for hand function, as deformities, spasticity, sensory deficits, and motor control impairments contribute to the functional limitations of the hand.

A large portion of tetraplegics experienced a lack of motor control, spasticity, and sensory deficits, which are common clinical features of cerebral palsy. Additionally, the significant chronological and developmental age gap for this group of children was evident (Table 12). Consequently, this group experienced the greatest degree of hand dysfunction. Regarding activities of daily living (ADL) performance, diplegics were expected to perform best due to their milder spasticity. However, tetraplegics performed worse than hemiplegics, with triplegics exhibiting similar WeeFIM quotients to normal subjects and being the most functional group overall. The presence of both upper limbs involved in the diplegic group resulted in less impact on scores.

For assessing treatment effectiveness, a standardized test to evaluate hand function deficits was necessary. While WeeFIM offers a broader evaluation, a more targeted approach could be more effective in treating cerebral palsy symptoms. MAULF instruction would be particularly beneficial for those experiencing challenges with motor coordination and postural control. WeeFIM assesses a child's ability to perform daily tasks, which includes using both hands during certain ADLs. This may give the impression that the affected hand has improved function due to compensation by the unaffected hand. For unilaterally affected patients, MAULF testing would not be feasible. The key factor in MAULF scores would be whether treatment leads to improved function, as opposed to simply adjusting to the condition.

Statistically significant correlations between MAULF, FHGT, and deformities of the hand and wrist were found in this study, with correlation coefficients of $r = -0.626$ and $p = 0.000$ for FHGT. Unlike MAULF, FHGT did not correlate with hand sensation. Nevertheless, MAULFs are not suitable for isolated analysis, as they merely indicate the level of dysfunction without clarifying the underlying cause. A review of recent literature revealed that there is no scientifically validated hand function assessment battery specifically designed for cerebral palsy patients. Participants in this study were recruited in 70% of cases, with 30% of guardians missing the appointment date for evaluation. In some cases, patients withdrew their consent during follow-up visits due to interruptions in schooling or other daily activities. Future research will aim to develop a more streamlined and simplified assessment tool, which would allow for accurate evaluation of both upper limb deformities and hand function. Based on the findings and limitations outlined, the authors recommend using MAULF and FHGT to assess hand function in cerebral palsy patients. There is also a need for further research to investigate whether MAULF and FHGT can effectively monitor treatment outcomes for these patients.

CONCLUSION

This study underscores the complex relationship between deformities, spasticity, sensory perception, and motor control in individuals with cerebral palsy,

particularly in relation to their upper limb function. The findings reveal that tetraplegics, despite their advanced age and developmental stage, exhibited the most significant functional impairments, largely due to a combination of motor control deficits, spasticity, and sensory deficits. While diplegics and triplegics generally exhibited better functional outcomes, the influence of bilateral involvement and the degree of spasticity were significant factors in determining hand function and daily activity performance.

The study also emphasizes the importance of using comprehensive and standardized assessment tools such as MAULF and FHGT for evaluating hand function. These tools provide valuable insights into the motor and sensory challenges faced by cerebral palsy patients and can inform treatment strategies. However, it is clear that fine motor skills alone do not account for hand function in this population, with deformities and sensory deficits playing a significant role. The limitations in the current assessment tools highlight the need for further research into more refined and effective methods for monitoring hand function and treatment outcomes in cerebral palsy patients.

Ultimately, the findings support the integration of tailored therapeutic interventions that focus on enhancing motor coordination, postural control, and addressing sensory deficits. Future research should focus on developing more streamlined, accessible, and reliable assessment methods to facilitate better management of cerebral palsy symptoms and improve long-term outcomes for affected individuals..

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