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Original Article

Physiotherapy Section

Multidomain Assessment of Hand Function in Children with Cerebral Palsy: A Cross-sectional Study

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ABSTRACT

Introduction: Cerebral Palsy (CP) is the leading cause of permanent physical disability in childhood, and upper limb involvement adversely affects Activities of Daily Living (ADL) and participation. Validated, multidomain assessment of hand function is essential for evidence-based intervention planning and outcome monitoring.

Aim: To characterise hand function using a comprehensive assessment tool in children with CP.

Materials and Methods: This cross-sectional study was conducted across rehabilitation centres near Ahmedabad and Gandhinagar, Gujarat, India over a period of ten months (August 2025 to May 2026), enrolling 66 children with confirmed CP aged 2.3 to 15 years (36 boys, 30 girls). Assessments comprised the Manual Ability Classification System (MACS), the ABILHAND-Kids Questionnaire (Rasch logit score), bilateral grip strength (hand dynamometry), tactile threshold (aesthesiometry), gross and fine dexterity {Box and Block Test (BBT) and Nine-Hole Peg Test (9HPT)}, and stereognosis. Shapiro-Wilk testing indicated significant departures from normality for the continuous variables; therefore, non parametric methods were used throughout (significance threshold $p<0.05$).

Results: Mean age was 6.56±3.04 years (median 6.0; range 2.3–15.0). Spastic diplegia was the most prevalent subtype 33 (50.0%). The median ABILHAND-Kids Questionnaire logit score was 0.27 (IQR: -0.26 to 1.95). CP subtype significantly differentiated ABILHAND-Kids Questionnaire logit scores (Kruskal–Wallis $H=14.45$, $p=0.013$); spastic diplegia showed the highest manual ability and dystonic CP the lowest. Bilateral BBT ($\rho=0.336$–0.359, $p<0.01$), 9HPT ($\rho=-0.283$ to -0.293, $p<0.05$), and stereognosis ($\rho=0.328$-0.352, $p<0.05$) correlated significantly with ABILHAND-Kids Questionnaire logit scores. Right-hand grip strength was significantly greater than left (Wilcoxon $p<0.001$). Gender (Mann–Whitney $p=0.079$) and MACS level (Kruskal–Wallis $p=0.907$) did not significantly differentiate ABILHAND-Kids Questionnaire scores.

Conclusion: Dexterity (BBT and 9HPT) and stereognosis were significantly associated with functional hand ability in children with CP. CP subtype was significantly associated with manual ability. A multidomain assessment approach is recommended for both clinical practice and research.

Keywords: Disability evaluation, Hand strength, Muscle spasticity, Psychomotor performance, Rehabilitation

INTRODUCTION

The CP is the leading cause of permanent motor disability in childhood, with a reported global prevalence of approximately 2-3 per 1,000 live births [1]. The condition encompasses a heterogeneous group of persistent, non-progressive disorders of movement and posture arising from disturbances to the developing foetal or infant brain [1]. Upper limb involvement occurs in the majority of affected individuals and substantially impairs performance of ADL, social participation, and overall quality of life [1,2].

Hand function in CP is inherently multidimensional, encompassing fine motor components such as grip strength and bimanual coordination, alongside somatosensory determinants including two-point tactile discrimination and stereognostic object recognition [2-5]. Comprehensive, multidomain assessment across each of these dimensions is essential to guide individualised rehabilitation planning in children with CP.

The ABILHAND-Kids Questionnaire is a Rasch-calibrated, parent-proxy measure of manual ability with well-established psychometric properties across a range of CP subtypes [2]. The MACS provides a five-level ordinal classification of functional hand use in daily activities and is widely used in both clinical and research contexts [3]. Performance-based instruments - including the BBT, 9HPT, hand dynamometry, aesthesiometry, and stereognosis - complement proxy-report tools by quantifying discrete functional domains with precision [4,5]. Despite the individual availability of these measures, a comprehensive multidomain assessment battery applied across the full spectrum of CP subtypes remains limited [6].

The objectives of the present study were to assess hand function in children with CP using a multidomain assessment battery and determine its association with functional manual ability; to compare ABILHAND-Kids Questionnaire logit scores across CP subtypes, MACS levels, gender, and age and to identify which performance-based measures correlate most strongly with functional manual ability.

The present analysis is based on baseline (pre-treatment) data derived from a larger, registered randomised controlled trial that is currently ongoing and has not yet been published or reported elsewhere. Accordingly, the multidomain hand-function data presented in this manuscript collected before intervention are original and do not overlap with any previous or concurrent publication. This manuscript is restricted to a cross-sectional analysis of pre-intervention assessment data; no post-intervention or treatment-outcome data from the parent trial are reported herein.

MATERIALS AND METHODS

This study presents a cross-sectional analysis of baseline (pre-intervention) data collected from children with cerebral palsy enrolled in an ongoing, registered randomised controlled trial. Data collection was conducted across rehabilitation centres near Ahmedabad and Gandhinagar, Gujarat, India, over a period of ten months (August 2025 to May 2026), prior to randomisation and initiation of any intervention. Ethical approval for the parent randomised controlled trial, from which this pre-intervention dataset was derived, was obtained from the Medilink Ethics Committee, Ahmedabad (approval letter dated 01 August 2023; ECR/344/Inst/GJ/2013/RR-16/RR-19; OHRP: IRB00008578).

Inclusion criteria: (i) confirmed diagnosis of CP by a paediatric neurologist; (ii) age between 2 and 16 years; and (iii) sufficient cognitive and communicative ability to cooperate with the assessment protocol.

Exclusion criteria: Children were excluded if they had undergone upper limb surgery within the preceding six months, had significant co-morbid conditions likely to interfere with assessment, or were unable to cooperate due to severe cognitive impairment.

Sample size calculation: The sample size was estimated using the standard single-proportion formula for cross-sectional/observational studies, consistent with the OpenEpi sample-size calculator: $n=Z^2PQ/L^2$,

where n=required sample size; Z=1.96, the standard normal deviate corresponding to a 95% confidence level; P=expected proportion of children with CP demonstrating clinically significant hand-function impairment, taken as 50% (P=0.5) in the absence of local prevalence data, since P=Q=0.5 yields the most conservative (maximum) sample size estimate; Q=(1 - P)=0.5; and L=12%, the absolute precision (margin of error) accepted for this estimate. Substituting these values:

$n=(1.96)^2\times0.5\times0.5/(0.12)^2=0.9604/0.0144\approx66.7\approx67$. The calculated minimum sample size was approximately 67 participants; within the predefined ten months recruitment period, 66 consecutive eligible children were enrolled and analysed, closely approximating the calculated requirement.

Study Procedure

All assessments were administered bilaterally by a single trained assessor to minimise inter-rater variability. The following instruments were used, together with the direction of interpretation for each score:

ABILHAND-Kids Questionnaire: A 21-item, Rasch-analysed parent-proxy measure assessing manual ability in daily activities on a three-point ordinal scale (impossible/difficult/easy), yielding a raw score and a calibrated Rasch logit person-ability score. A higher raw score or logit score indicates greater manual ability; a lower score indicates greater difficulty performing bimanual daily activities [2]. Although the standard ABILHAND-Kids questionnaire was validated for children aged 6-15 years, a newer version, the ABILHAND-Kids Young CP, has since been validated for children aged 2-7 years [7], thereby supporting its use across the full age range of the present study (2.3-15 years). The standard ABILHAND-Kids questionnaire comprises 21 items, whereas the ABILHAND-Kids Young CP version comprises 17 items. Although the two versions differ in item content and number, both were developed using Rasch measurement methodology within the same ABILHAND family of instruments. For each version, parents rate the child's perceived difficulty performing every applicable item as impossible, difficult, or easy; these ordinal item ratings are summed to give a raw score and are then converted, via Rasch analysis, into an interval-level logit score calibrated specifically for that version. Because the resulting logit scores are expressed on a common linear measurement scale rather than on the original raw item scale, scores generated from the two age-appropriate versions were comparable and could be pooled for analysis across the full study age range, despite the difference in the underlying raw item sets. The questionnaire was completed by parents as a proxy-report measure of the child's everyday manual ability, rather than as a direct assessment of the child. As the parent trial required a single manual-ability measure applicable to all enrolled children, scores obtained for the youngest participants were interpreted with additional caution. Raw ABILHAND-Kids scores were subsequently converted to logit scores using Rasch analysis for data processing.

Manual Ability Classification System (MACS): A five-level ordinal system describing how children handle objects in daily activities, from Level I (handles objects easily and successfully) to Level V (does not handle objects). A lower MACS level (I) denotes better manual ability, while a higher level (III-V) denotes greater limitation [3]. The MACS was administered to children aged 4-15 years, consistent with its validated age range. For younger participants (aged 2 to <4 years), the Mini-MACS - a downward extension of the MACS designed for children aged 1-4 years [8] was administered instead. As both instruments employ an identical five-level ordinal scale (I-V), scores obtained using the two versions were pooled and are presented jointly.

Box and Block Test (BBT): A measure of unilateral gross manual dexterity recording the number of 2.5-cm wooden blocks transferred across a partition within 60 seconds. A higher score (more blocks transferred) indicates greater dexterity; a lower score indicates poorer dexterity [4].

Nine-Hole Peg Test (9HPT): A timed measure of fine motor dexterity recording the seconds required to sequentially place and remove nine pegs from a pegboard. A lower completion time (fewer seconds) denotes superior fine motor performance; a higher completion time denotes slower, less precise fine motor control [4].

Hand dynamometry: Bilateral grip strength was recorded in kilograms using a calibrated Jamar hydraulic dynamometer (Sammons Preston Rolyan, Bolingbrook, IL, USA) with the elbow at 90° flexion and the shoulder in neutral position. A higher value (kg) denotes greater grip strength; a lower value denotes weaker grip [5].

Aesthesiometry: Bilateral two-point tactile discrimination threshold was assessed in centimetres using a calibrated two-point Aesthesiometer applied to the volar fingertip. A smaller threshold distance (cm) denotes better (finer) tactile discrimination; a larger threshold distance denotes poorer tactile discrimination [9]. Seven participants (10.6%) were unable to cooperate and were recorded as Not Testable (NT).

Stereognosis: Tactile object recognition was assessed using a standardised set of 15 common objects presented individually with vision occluded. A higher score (out of 15) reflects better haptic object recognition; a lower score reflects impaired tactile object recognition [10]. Seven participants (10.6%) were recorded as NT.

STATISTICAL ANALYSIS

All statistical analyses were performed using Python 3 (SciPy 1.11; pandas 2.0). Normality of distribution for each continuous variable was evaluated using the Shapiro-Wilk test. Since all variables were non normally distributed ($p<0.05$ for all), non parametric procedures were applied throughout. Continuous variables are presented as median (IQR); Mean±SD is additionally reported for descriptive comparison. Bivariate associations between performance-based measures and ABILHAND-Kids Questionnaire logit scores were examined using Spearman rank correlation (ρ). Group comparisons were conducted using the Kruskal-Wallis H test (CP subtype, MACS level, age group: ≤6 years vs. > 6 years), the Mann-Whitney U test (gender comparison), and the Wilcoxon signed-rank test (bilateral, right-vs-left comparisons). Statistical significance was defined as $p<0.05$ (two-tailed) for all analyses. Aesthesiometry and stereognosis data were unavailable for seven participants (10.6%) who were unable to cooperate with sensory testing and were recorded as NT; these participants were excluded on a domain-specific basis from the corresponding descriptive and correlation analyses (n=59), while remaining included in all other outcome measures (n=66).

RESULTS

Demographic and Clinical Characteristics

A total of 66 children with CP were enrolled. The sample comprised 36 boys (54.5%) and 30 girls (45.5%), with a mean age of 6.56±3.04 years (median: 6.0 years; range: 2.3-15.0 years). Spastic diplegia was the most prevalent CP subtype, 33 (50.0%), followed by dystonic CP, 9 (13.6%), spastic triplegia, 9 (13.6%), left hemiplegia, 6 (9.1%), spastic quadriplegia, 6 (9.1%), and right hemiplegia, 3 (4.5%). Right-side dominance was recorded in 39 children (59.1%). MACS classification was Level-I in 19 (28.8%), Level-II in 38 (57.6%), and Level-III in 9 (13.6%) participants. Full demographic details are presented in [Table/Fig-1].

Variables	Category	n (%)	Mean±SD	Median (IQR)
Age (years)	–	–	6.56±3.04	6.0 (4.85–8.0)
Gender	Male	36 (54.5%)	–	–
	Female	30 (45.5%)	–	–
Dominant side	Right	39 (59.1%)	–	–
	Left	27 (40.9%)	–	–
MACS level	Level-I	19 (28.8%)	–	–
	Level-II	38 (57.6%)	–	–
	Level-III	9 (13.6%)	–	–
CP subtype	Spastic Diplegic	33 (50.0%)	–	–
	Dystonic	9 (13.6%)	–	–
	Spastic Triplegic	9 (13.6%)	–	–
	Left Hemiplegia	6 (9.1%)	–	–
	Spastic Quadriplegic	6 (9.1%)	–	–
	Right Hemiplegia	3 (4.5%)	–	–

[Table/Fig-1]: Demographic and clinical characteristics of study participants (N=66).
MACS: Manual Ability Classification System; CP: Cerebral Palsy; IQR: Interquartile Range. MACS levels shown were classified using the standard MACS for children aged 4-15 years and the Mini-MACS for children aged 2 to under 4 years; both use an equivalent I–V ordinal scale.

Descriptive Statistics of Outcome Measures

Descriptive statistics for all outcome measures are summarised in [Table/Fig-2]. The median ABILHAND-Kids Questionnaire logit score was 0.27 (mean: 0.77±1.26). Mean BBT scores were 20.82±11.05 (right) and 20.92±12.00 (left) blocks per minute. Mean 9HPT completion times were 71.67±35.11 seconds (right) and 80.53±38.43 seconds (left), with longer left-hand times consistent with right-hand dominance in the majority of participants.

Right-hand grip strength (5.05±2.80 kg) was significantly greater than left-hand grip strength (4.02±2.02 kg; Wilcoxon signed-rank p<0.001). Bilateral BBT (right 20.82±11.05 vs. left 20.92±12.00 blocks/min; p=0.581), 9HPT (right 71.67±35.11 vs. left 80.53±38.43 sec; p=0.131), aesthesiometry (right 1.92±0.75 vs. left 1.92±0.93 cm; p=0.989), and stereognosis (right 9.00±5.69 vs. left 9.14±5.59; p=0.546) did not differ significantly between the right and left hands (all p>0.05, Wilcoxon signed-rank test) [Table/Fig-3].

Outcome measure	N (valid)	Mean±SD	Median	IQR
ABILHAND-Kids questionnairelogit score	66	0.77±1.26	0.27	-0.26 to 1.95
ABILHAND-Kids questionnaireraw score (0-42)	66	22.21±7.24	20.00	16.00-29.75
Hand dynamometer - right (kg)	66	5.05±2.80	4.20	3.40-6.00
Hand dynamometer - left (kg)	66	4.02±2.02	4.00	2.50-5.00
Aesthesiometer - right (cm)	59	1.92±0.75	2.00	1.00-2.00
Aesthesiometer - left (cm)	59	1.92±0.93	2.00	1.00-2.00
Box and block test - right (blocks/min)	66	20.82±11.05	19.00	11.25-25.00
Box and block test - left (blocks/min)	66	20.92±12.00	20.50	12.00-28.00
Nine-hole peg test - right (sec)	66	71.67±35.11	67.00	40.25-92.00
Nine-hole peg test - left (sec)	66	80.53±38.43	77.00	59.00-98.00
Stereognosis - Right (score/15)	59	9.00±5.69	11.00	3.00-14.00
Stereognosis - Left (score/15)	59	9.14±5.59	12.00	3.00-15.00

[Table/Fig-2]: Descriptive statistics of outcome measures.
SD: Standard Deviation; 9HPT: Nine-Hole Peg Test; sec: seconds. N=59 (rather than 66) for the aesthesiometry and stereognosis rows because seven of the 66 enrolled children (10.6%) were unable to cooperate with sensory testing and were recorded as NT; these seven were excluded from the corresponding descriptive and correlation analyses only, and remained included in all other outcome measures.

Measures	Right (Mean±SD)	Left (Mean±SD)	Wilcoxon p-value
Hand dynamometer (kg)	5.05±2.80	4.02±2.02	<0.001**
Box and block test (blocks/min)	20.82±11.05	20.92±12.00	0.581
Nine-hole peg test (sec)	71.67±35.11	80.53±38.43	0.131
Aesthesiometer (cm)	1.92±0.75	1.92±0.93	0.989
Stereognosis (score/15)	9.00±5.69	9.14±5.59	0.546

[Table/Fig-3]: Wilcoxon signed-rank test - right vs. left hand comparisons.
SD: Standard Deviation. p<0.05 considered statistically significant (two-tailed). **p<0.001

ABILHAND-Kids Questionnaire Logit Scores by Cerebral Palsy (CP) Subtype

Kruskal-Wallis testing revealed a statistically significant difference in ABILHAND-Kids Questionnaire logit scores across CP subtypes (H=14.45, p=0.013). Children with spastic diplegia achieved the highest mean logit scores (1.29±1.41), followed by right hemiplegia (1.07±0.10) and spastic triplegia (0.75±0.85). Children with spastic quadriplegia recorded intermediate scores (0.18±1.09), while left hemiplegia (-0.09±0.36) and dystonic CP (-0.26±0.44) recorded the lowest scores, falling below the Rasch scale midpoint. Subtype-stratified logit data are presented in [Table/Fig-4].

CP subtype	n	Logit (Mean±SD)	Median logit
Spastic diplegic	33	1.29±1.41	2.01
Right hemiplegia	3	1.07±0.10	1.01
Spastic triplegic	9	0.75±0.85	1.18
Spastic quadriplegic	6	0.18±1.09	–0.33
Left hemiplegia	6	–0.09±0.36	–0.07
Dystonic	9	–0.26±0.44	–0.26

[Table/Fig-4]: ABILHAND-Kids questionnaire logit scores stratified by CP subtype.
Higher logit score=greater bimanual manual ability. Kruskal-Wallis H=14.45, p=0.013.

Effect of gender, MACS Level, and age group: Gender did not significantly differentiate ABILHAND-Kids Questionnaire logit scores (Mann–Whitney U=403.5, p=0.079), although girls showed numerically higher median scores (median 1.09) than boys (median 0.00) are presented [Table/Fig-5]. MACS level also did not significantly differentiate logit scores (Kruskal-Wallis H=0.20, p=0.907), despite a numerically descending trend from Level-I (mean 0.90±1.27) through Level-II (mean 0.73±1.31) to Level-III (mean 0.68±1.15). Age group (≤6 years vs. >6 years) also showed no significant difference (Mann–Whitney U=488.0, p=0.679), despite older children having a numerically higher median score (1.09) than younger children (0.20).

Correlation of performance measures with ABILHAND-Kids questionnaire logit scores: Spearman's rank correlation analysis identified statistically significant associations between ABILHAND-Kids Questionnaire logit scores and three performance domains. Bilateral BBT scores demonstrated significant positive correlations

Grouping variables	Category	n	Logit (Mean±SD)	Median logit	Test statistic	p-value
Gender	Male	36	0.52±1.20	0.00	Mann-Whitney U=403.5	0.079
	Female	30	1.08±1.28	1.09	–	–
MACS Level	Level-I	19	0.90±1.27	1.01	Kruskal-Wallis H=0.20	0.907
	Level-II	38	0.73±1.31	0.27	–	–
	Level-III	9	0.68±1.15	0.27	–	–
Age group	≤6 years	40	0.69±1.23	0.20	Mann–Whitney U=488.0	0.679
	> 6 years	26	0.90±1.32	1.09	–	–

[Table/Fig-5]: ABILHAND-kids questionnaire logit scores by gender, MACS level, and age group.
SD: Standard Deviation; MACS: Manual Ability Classification System. $p<0.05$ considered statistically significant (two-tailed).

(right: ρ=0.336, p=0.006; left: ρ =0.359, p=0.003). Bilateral 9HPT completion time showed significant negative correlations (right: ρ=-0.293, p=0.017; left: ρ=-0.283, p=0.021), indicating that faster fine motor performance was associated with greater functional manual ability on both sides. Bilateral stereognosis scores demonstrated significant positive correlations (right: ρ=0.352, p=0.006; left: ρ =0.328, p=0.011). Hand dynamometry, aesthesiometry, and age did not yield statistically significant correlations with logit scores (all p>0.05). Complete correlation data are presented in [Table/Fig-6].

Outcome measure	Spearman ρ	p-value
Age (years)	–0.015	0.907
Hand dynamometer - Right (kg)	0.145	0.245
Hand dynamometer - left (kg)	0.116	0.355
Aesthesiometer - right (cm)	0.007	0.960
Aesthesiometer - left (cm)	–0.030	0.824
Box and block test - right (blocks)	0.336	0.006**
Box and block test - left (blocks)	0.359	0.003**
Nine-hole peg test — right (sec)	–0.293	0.017*
Nine-hole peg test - left (sec)	–0.283	0.021*
Stereognosis - right (score)	0.352	0.006**
Stereognosis - left (score)	0.328	0.011*

[Table/Fig-6]: Spearman's rank correlation of performance measures with ABILHAND-kids questionnaire logit scores.
ρ=Spearman correlation coefficient. *p<0.05; **p<0.01. Negative ρ for 9HPT indicates faster time (lower seconds)=better function

DISCUSSION

Principal Findings

The present study applied a multidomain assessment battery - spanning parent-reported manual ability, performance-based dexterity, grip strength, tactile threshold, and stereognosis - to 66 children representing the several clinical subtypes of CP Gross and fine dexterity (BBT and 9HPT) and stereognosis correlated significantly with ABILHAND-Kids Questionnaire logit scores, whereas grip strength, aesthesiometric threshold, gender, and MACS level did not. CP subtype, in contrast, was a strong and significant determinant of manual ability. These findings support calls for comprehensive, multidomain evaluation of upper-limb function in children with CP rather than reliance on any single instrument [6].

Dexterity and Sensory Measures as Correlates of Manual Ability

The significant associations between ABILHAND-Kids Questionnaire scores and both BBT and 9HPT performance are consistent with the conceptual view of manual ability as an activity-level construct integrating gross and fine dexterity, since both tests require planning, transport, and release of objects - component skills also captured by parent-report items. Contemporary neuroimaging work in unilateral CP has similarly linked BBT-measured dexterity to MACS-defined functional level [11], reinforcing that the BBT indexes functionally meaningful variance rather than isolated psychomotor speed. The moderate correlation magnitudes observed here (BBT ρ =0.336–0.359; 9HPT ρ=-0.283 to -0.293) are consistent with recent reliability work establishing the 9HPT as a sensitive, reproducible measure of paediatric dexterity in unilateral spastic CP [12,13], while also indicating that performance-based dexterity and questionnaire-based manual ability, although related, are not interchangeable constructs [14]. Bilateral stereognosis scores showed comparable correlation strength (ρ=0.328–0.352), corroborating literature identifying somatosensory object recognition as a determinant of functional hand use that is at least partly independent of motor impairment [5,9,10]. Because sensory deficits in CP are common yet frequently under-assessed in routine practice [10], these findings suggest that stereognosis testing adds discriminative value beyond motor assessment alone, with direct relevance for intervention planning: motor-only training may fail to address a sensory-based ceiling on function [15]. By contrast, two-point aesthesiometric threshold did not correlate significantly with manual ability, despite the biological plausibility of a sensorimotor link. This may reflect the coarse resolution of centimetre-scale thresholds relative to the discriminative demands of stereognosis, a restricted range in this sample (median 2.00 cm, IQR 1.00-2.00 cm), or the substantial proportion of children unable to complete testing (10.6% recorded as NT), which reduced effective sample size and variance. Comparable difficulty achieving consistent, discriminative threshold measurement in children with CP has been reported previously [9,10], suggesting aesthesiometry may be more useful as a categorical (intact/impaired) than a continuous outcome in this population. It should also be noted that BBT normative data are established for children aged six years and older [4,16]; the youngest participants in the present cohort (as young as 2.3 years) fell outside this normative range, and although the internal correlation with ABILHAND-Kids Questionnaire logit scores reported here does not depend on external norms, age-appropriate normative comparison should be interpreted cautiously in very young children.

Effect of Cerebral Palsy (CP) Subtype

The CP subtype significantly differentiated manual ability, with spastic diplegia showing the highest ABILHAND-Kids Questionnaire logit differed significantly across CP subtypes, with the highest mean score observed in spastic diplegia and the lowest in dystonic CP. This pattern is consistent with the pathophysiological distinction between spasticity, in which excessive but relatively predictable tone permits compensatory motor strategies, and dystonia, in which fluctuating involuntary movement disrupts the consistency of goal-directed reach and grasp - a distinction that underlies why contemporary CP classification separates motor-type subtypes for both epidemiological and clinical purposes [17]. The relatively preserved manual ability in spastic diplegia, where upper-limb involvement is typically milder than lower-limb involvement, is consistent with prior descriptions of the topographical and motor-type heterogeneity underlying variable hand function in CP [6,18]. Right hemiplegia showed relatively preserved logit scores whereas left hemiplegia scored below the scale midpoint; this asymmetry may relate to differential effects of left- versus right-hemisphere injury on motor planning and interlimb coordination described in unilateral CP [19,20].

Grip Strength, Gender, MACS Level, and Age

Right-hand grip strength significantly exceeded left-hand grip strength, consistent with the predominance of right-hand dominance (59.1%) in this cohort; however, grip strength itself did not correlate with ABILHAND-Kids Questionnaire scores. This dissociation is consistent with evidence that muscle weakness in CP arises from complex central and peripheral mechanisms - including impaired selective motor control, co-contraction, and secondary musculoskeletal adaptation - that do not translate linearly into functional task performance [21], and aligns with reviews concluding that isolated strengthening produces only modest functional carry-over unless embedded in task-specific practice [22]. Neither gender, age group nor MACS level significantly differentiated ABILHAND-Kids Questionnaire scores, although a non significant descending trend was observed across MACS levels I–III. This contrasts with cohort studies linking MACS level to other functional and cognitive outcome measures [23], and may reflect the restricted MACS range sampled here (Levels I-III only, with no Level-IV or V participants), limited power in the smallest subgroup (Level-III, n=9), and possible ceiling effects on the ABILHAND-Kids Questionnaire scale in a cohort with predominantly ambulatory, mild-to-moderate involvement. This finding suggests that MACS classification alone should not substitute for detailed multidomain testing, particularly at the milder end of the disability spectrum represented in this sample.

Collectively, these findings support incorporating dexterity (BBT, 9HPT) and stereognosis testing alongside MACS classification and parent-reported outcome measures in routine multi-domain evaluation of children with CP, consistent with calls for comprehensive upper-limb assessment batteries in this population [6]. Because dexterity and sensory measures, rather than strength or ordinal classification, were most closely associated with functional manual ability, intervention strategies combining task-specific dexterity training with sensory re-education - such as constraint-induced movement therapy and other evidence-based upper-limb therapies [24-26] - may be better targeted to the mechanisms underlying functional limitation than strength training alone.

Limitation(s)

Several limitations should be noted. The cross-sectional, single-timepoint design precludes causal inference, and participants were drawn from rehabilitation centres in a single geographic region, which may limit generalisability. Correlation magnitudes for BBT, 9HPT, and stereognosis, although statistically significant, were of small-to-moderate strength ($\rho \approx 0.28$-0.36). This suggests that other unmeasured factors, including cognition, visual perception, and bimanual coordination not directly captured by the unilateral performance tests, may also contribute to functional manual ability. Dedicated bimanual assessment tools were not included in this battery and represent an important direction for future work [27]. The sample also included children as young as 2.3 years, at the lower boundary of standard ABILHAND-Kids Questionnaire validation; the recently developed ABILHAND-Kids Young CP instrument, calibrated specifically for children aged 2-7 years, offers a promising tool for extending this multidomain approach to very young children with CP in future studies [7]. Finally, aesthesiometry and stereognosis data were unavailable for 10.6% of participants who could not cooperate with sensory testing, introducing a modest missing-data limitation for these two domains.

CONCLUSION(S)

The present study demonstrated that dexterity (BBT, 9HPT) and stereognosis, rather than grip strength or MACS level, are the measures most strongly associated with functional manual ability in children with CP, and that CP subtype remains a significant determinant of performance, with spastic diplegia showing the highest manual ability and dystonic CP the lowest. A multidomain assessment approach, combining performance-based and parent-reported measures, is therefore recommended for both clinical practice and research. Future longitudinal, multicentre studies incorporating dedicated bimanual assessment and validated instruments for younger children would help confirm and extend the present findings.

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