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Clinometric Evaluation of the Bruininks-Oseretsky Test of Motor Proficiency (Second Edition) Bilateral Coordination Subtest in Children with Cerebral Palsy: A Cross-Sectional Study

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ABSTRACT

Background: Cerebral palsy (CP) is a neurodevelopmental disorder characterized by impaired motor control, coordination deficits, and functional limitations. Bilateral coordination skills are essential for participation in daily activities, yet their reliable measurement remains challenging. The Bruininks–Oseretsky Test of Motor Proficiency, Second Edition (BOT-2) and the Developmental Coordination Disorder Questionnaire (DCDQ) are commonly used to evaluate motor skills. However, the minimal detectable change (MDC) and minimal clinically important difference (MCID) for BOT-2 bilateral coordination subtest in children with CP remain underexplored.

Objective: To establish the MDC and MCID for the BOT-2 bilateral coordination subtest in children with CP and to compare them with DCDQ values.

Methods: This cross-sectional study involved 78 children with CP (mean age 10.35 ± 2.73 years; GMFCS Levels I–II) recruited from special schools. Participants underwent the BOT-2 bilateral coordination subtest and DCDQ at baseline, one week, and four weeks. Reliability was analyzed using intraclass correlation coefficients (ICC). Standard error of measurement (SEM), MDC at 95% confidence (MDC95), and MCID were calculated using distribution- and anchor-based approaches.

Results: The BOT-2 bilateral coordination subtest showed excellent reliability (ICC = 0.99, 95% CI: 0.98–0.99). SEM was 0.30, yielding an MDC95 of 0.84. The MCID, derived using anchor-based methods, was 1.92. In comparison, the DCDQ demonstrated an SEM of 0.97, MDC95 of 2.69, and distribution-based MCID of 2.31. Standardized response mean was higher for BOT-2 (0.80) than for DCDQ (0.21), indicating superior responsiveness.

Conclusion: The BOT-2 bilateral coordination subtest is a reliable and sensitive tool for detecting meaningful improvements in children with CP. A change of ≥1.92 points represent clinically significant progress, whereas DCDQ complements BOT-2 by capturing parent-perceived outcomes. Together, they offer a robust framework for outcome evaluation in pediatric neurorehabilitation.

Keywords: Cerebral Palsy, Bilateral Coordination, BOT-2, DCDQ, Rehabilitation, Clinometric

INTRODUCTION

encompasses a group of permanent, non-progressive disorders of posture and movement resulting from disturbances in the developing fetal or infant brain. In addition to motor impairments, children with CP often present with sensory, perceptual, cognitive, and behavioral difficulties, which collectively limit participation in daily activities. Recent estimates place the global prevalence of CP at approximately 2.95 per 1000 live births, with higher prevalence observed in mixed rural–urban populations compared to either rural or urban groups alone.

Motor impairments in CP manifest as abnormal muscle tone, weakness, spasticity, involuntary movements, and impaired balance and coordination. Among these, bilateral coordination is particularly critical, as it underpins tasks such as walking, running, dressing, eating, and academic activities like writing or using scissors. Impairment in bilateral coordination not only restricts functional independence but also affects cognitive and social development. Research has established associations between bilateral coordination deficits and reduced performance in reading, mathematics, and organizational skills.

Accurate and sensitive outcome measures are essential for evaluating therapeutic progress in CP. The Bruininks–Oseretsky Test of Motor Proficiency, Second Edition (BOT-2), is widely recognized for assessing motor function across four domains: fine manual control, manual coordination, body coordination, and strength and agility. Its bilateral coordination subtest directly examines synchronous and asynchronous movements of the upper and lower limbs, making it particularly relevant for CP populations. Complementary to BOT-2, the Developmental Coordination Disorder Questionnaire (DCDQ) provides a parent-reported assessment of motor performance in functional contexts.

While both BOT-2 and DCDQ are validated tools, clinical interpretation of changes in scores requires benchmarks that distinguish genuine improvement from measurement error. The concepts of minimal detectable change (MDC) and minimal clinically important difference (MCID) provide such benchmarks. MDC represents the smallest change beyond measurement error, whereas MCID reflects the smallest improvement considered meaningful by patients or clinicians. Although MDC and MCID values have been reported for BOT-2 subtests such as balance and manual dexterity, data for the bilateral coordination subtest remain scarce.

Establishing MDC and MCID values for BOT-2 bilateral coordination in CP populations is essential for guiding evidence-based decision-making in rehabilitation. This study addresses this gap by determining MDC and MCID for BOT-2 bilateral coordination and comparing these findings with values derived from the DCDQ.

MATERIALS & METHODS

Study Design and Setting

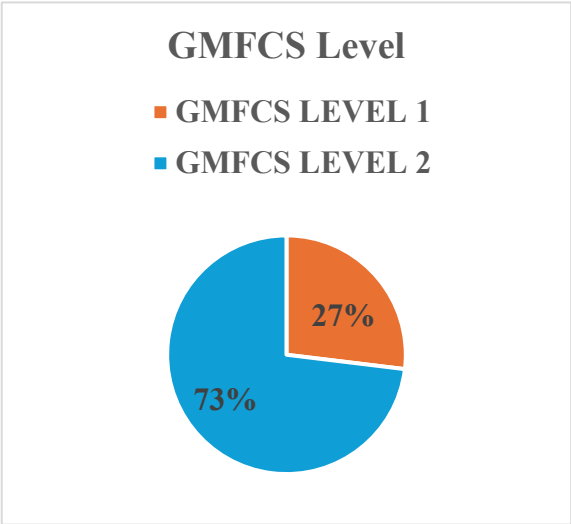
A cross-sectional analytical design was adopted. Data collection was conducted across special schools with integrated physiotherapy centers in urban regions. The study duration was 18 months. Ethical approval was obtained from the institutional review board, and informed consent and assent were collected from parents and participants respectively.

Participants

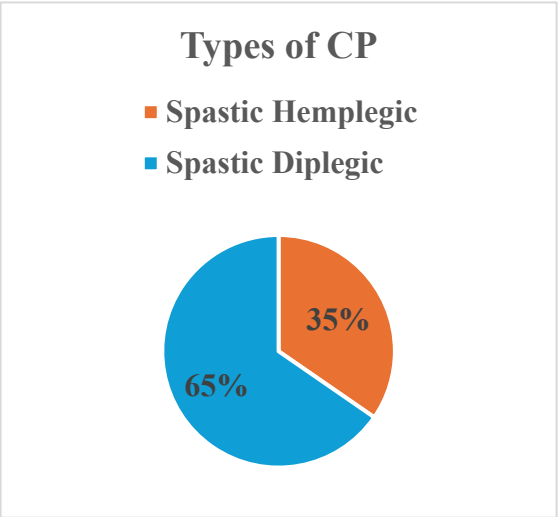
Seventy-eight children diagnosed with CP were recruited using convenience sampling. Inclusion criteria were:

- Age between 6 and 18 years.
- Gross Motor Function Classification System (GMFCS) levels I or II.
- Ability to understand and follow instructions.
- Participation in ongoing rehabilitation programs.

Exclusion criteria included uncontrolled seizures, uncorrected visual or auditory impairments, and unwillingness to participate.



Graph 1. GMFCS LEVEL



Graph 2. Types of CP

Sample Size

Sample size was determined using Open Epi software, with an assumed prevalence of 5%, absolute precision of 5%, and confidence level of 95%. This yielded a sample of 73, which was rounded up to 78 to account for potential dropouts.

Outcome Measures

1. **BOT-2 Bilateral Coordination Subtest**
   - Includes seven tasks: nose touching, jumping jacks, synchronized and asynchronous jumping, thumb–finger pivoting, and synchronized/asynchronous tapping of feet and fingers.
   - Scoring was performed according to standardized BOT-2 guidelines. Reliability and validity of BOT-2 have been established in previous literature (validity 0.73–0.90; reliability >0.95).
2. **DCDQ (2007 edition)**
   - A 15-item parent questionnaire assessing control during movement, fine motor/handwriting, and general coordination.
   - Items rated on a five-point Likert scale, with higher scores indicating better motor performance.

PROCEDURE

Participants were assessed at three time points: baseline (T1), one week later (T2), and four weeks later (T3). At each session, BOT-2 bilateral coordination subtests were administered, and parents completed the DCDQ. Assessments were conducted by trained physiotherapists to ensure standardization.

STATISTICAL ANALYSIS

Data analysis was performed using IBM SPSS Statistics 25. Descriptive statistics (mean, SD) were calculated for demographic variables. Test–retest reliability was evaluated using intraclass correlation coefficients (ICC, model 2,1). SEM was derived as SD × √(1 – r). MDC95 was calculated as 1.96 × √2 × SEM. MCID for BOT-2 was determined using anchor-based methods with DCDQ as the anchor, whereas MCID for DCDQ was estimated using a distribution-based approach (0.5 × SD). Responsiveness was assessed using standardized response mean (SRM).

RESULT

Participant Characteristics: Of the 78 participants, 67% were male. Most children (73%) were classified as GMFCS Level II,

and spastic diplegia was the most common subtype (65%).

Tabel 1. Test-retest reliability of two Bilateral Coordination tests

	T1	T2	T3	ICC (95% CI)
BOT-2	7.61±2.47	8.44±2.54	11.47±2.57	0.99 (0.98-0.99)
DCDQ	23.82±4.61	23.87±4.62	24.80±4.70	0.99 (0.98-0.99)

T1: baseline; T2: one week later; T3: four weeks later; ICC: intraclass correlation coefficient; CI: confidence interval; DCDQ: The developmental coordination disorder questionnaire; BOT-2: the Bilateral coordination subtest of Bruininks-Oseretsky test of motor proficiency-second Edition.

Table 2. MDC95 AND MCID of DCDQ

SD	r	SRM	SEM	MDC95	MCID
1.03	0.99	0.80	0.30	0.84	1.92

SD: standard deviation; r: test-retest reliability; SRM: standardized response mean; SEM: standard error of measurement; MDC95: minimum detectable change; MCID: minimum important difference.

Table 3. MDC95 AND MCID of DCDQ

SD	r	SRM	SEM	MDC95	MCID
4.61	0.99	0.21	0.97	2.69	2.31

SD: standard deviation; r: test-retest reliability; SRM: standardized response mean; SEM: standard error of measurement; MDC95: minimum detectable change; MCID: minimum important difference.

Reliability and Change Scores:

- BOT-2 demonstrated near-perfect reliability (ICC = 0.99). SEM was 0.30, MDC95 = 0.84, and MCID = 1.92.
- DCDQ also showed high reliability (ICC = 0.99). SEM was 0.97, MDC95 = 2.69, and MCID = 2.31.
- BOT-2 responsiveness (SRM = 0.80) was much higher than that of DCDQ (SRM = 0.21).
- A strong correlation (r = 0.91) was found between BOT-2 and DCDQ scores, supporting concurrent validity.

DISCUSSION

The present study evaluated and compared the Minimal Detectable Change (MDC) and Minimal Clinically Important Difference (MCID) of the BOT-2 Bilateral Coordination subtest and the Developmental Coordination Disorder Questionnaire (DCDQ) in children with cerebral palsy (CP). The findings provide important insights into the psychometric properties, responsiveness, and clinical utility of these measures in pediatric neurorehabilitation.

The BOT-2 bilateral coordination component demonstrated excellent measurement precision, as reflected by its low SEM (0.30) and MDC_{95} (0.84), coupled with a very high test-retest reliability (r = 0.99). The MCID value of 1.92 indicates that relatively small score improvements can be interpreted as clinically meaningful. Importantly, nearly 78% of participants exceeded this threshold, demonstrating not only statistical but also clinical significance. The SRM of 0.80, classified as large by Cohen's criteria, further confirmed that BOT-2 is highly responsive to change. These results support the utility of BOT-2 in identifying subtle yet functionally relevant improvements in motor coordination, consistent with prior reports highlighting its sensitivity in children with neurodevelopmental disorders (Franchignoni et al., 2014; Wuang et al., 2021).

By contrast, the DCDQ displayed higher measurement error (SEM = 0.97, MDC_{95} = 2.69) and a lower SRM (0.21), reflecting limited responsiveness compared to BOT-2. Despite strong reliability (r = 0.99), its higher MCID (2.31) suggests that larger score changes are necessary before they are perceived as clinically relevant. These findings are consistent with earlier critiques (Missiuna et al., 2006), which highlighted the questionnaire's limitations in detecting intervention-related changes. The reliance on parent-reported outcomes may explain this

variability, as subjective interpretation can introduce bias. Nevertheless, the DCDQ offered value as an anchor, facilitating the derivation of a clinically meaningful threshold for the BOT-2.

Comparisons with earlier work on other BOT-2 domains reinforce its sensitivity across motor skills. For instance, Kim et al. reported MCID values of 2.54 (anchor-based) and 1.38 (distribution-based) for the balance subtest, while Pawar and Satralkar found an MCID of 0.925 for manual dexterity in CP populations. The present findings align with these results, suggesting that BOT-2 consistently provides clinically interpretable change scores across motor domains.

The methodology applied here further strengthens interpretability. MCID for BOT-2 was calculated through an anchor-based approach using the DCDQ, while MCID for the DCDQ was estimated via a distribution-based method. Although distribution methods lack patient-centered context, they are frequently used when direct feedback categories are unavailable. Prior literature has recommended the "half standard deviation" rule as a pragmatic and conservative estimate of clinically meaningful change (Norman et al., 2003; Sloan et al., 2003). This strategy, combined with anchor-based estimation, ensured that both objective and subjective perspectives were incorporated, aligning with methodological recommendations by Revicki et al. (2020) and Ousmen et al. (2018).

Taken together, these results indicate that BOT-2 is a more robust tool for detecting performance-based improvements, while the DCDQ provides complementary parent-reported insights. Using both measures in combination offers a more comprehensive understanding of functional progress in children with CP. The dual-method approach to MCID estimation further enhances clinical interpretability, supporting the integration of these tools in both clinical and research settings.

CONCLUSION

The present study highlights the clinical utility of the BOT-2 bilateral coordination subtest and the Developmental Coordination Disorder Questionnaire (DCDQ) in children with cerebral palsy (CP). Findings demonstrated that the BOT-2 bilateral coordination subtest is both reliable and sensitive, with a minimal clinically important difference (MCID) of 1.92 and a minimal detectable change at 95% confidence (MDC_{95}) of 0.84. These thresholds confirm its usefulness in detecting genuine motor improvements rather than random variations. On the other hand, the DCDQ, though lacking well-defined global change categories, showed strong reliability, with an MCID of 2.31 (based on 0.5 × SD) and an MDC_{95} of 2.69. Importantly, the use of the DCDQ as an anchor helped reinforce the clinical interpretation of BOT-2 outcomes. Taken together, these tools provide a complementary assessment strategy, offering both objective performance-based data and parent-reported perspectives on functional change.

Limitations

Despite the strengths of this study, several limitations should be noted. First, subgroup analyses according to Gross Motor Function Classification System (GMFCS) levels, age categories, or CP subtypes were not performed, restricting the ability to examine whether findings vary across these groups. Second, the follow-up period was relatively short (four weeks), which may not be sufficient to capture sustained improvements, long-term functional changes, or potential relapses.

Clinical Implications

The results offer several valuable applications for clinical practice. The identification of a 1.92-point MCID on the BOT-2 bilateral coordination subtest provides clinicians with a practical benchmark to assess the effectiveness of interventions. If a child demonstrates an improvement equal to or greater than this

threshold, the gain can be interpreted as both statistically valid and clinically meaningful. Similarly, the MDC of 0.84 ensures that even smaller changes can be confidently distinguished from measurement error.

This evidence allows therapists to set clear, measurable treatment goals. For example, a two-point increase in BOT-2 scores can be communicated as a tangible marker of meaningful progress, thereby fostering motivation and trust among families. Moreover, therapists can make informed clinical decisions: less than 0.84 points may indicate no true improvement, changes between 0.84 and 1.92 points suggest real but not yet clinically important progress, and improvements beyond 1.92 points reflect significant functional gains warranting continuation or scaling of current strategies. The feasibility of using BOT-2 across physiotherapy, occupational therapy, and developmental pediatric settings further enhances its value as a cross-disciplinary assessment tool.

Future Scope

Future research should broaden the scope of analysis beyond bilateral coordination to include other BOT-2 subtests, such as balance, strength, and fine motor skills. Establishing similar benchmarks across multiple domains could provide clinicians with a comprehensive framework for assessing motor function in CP. Larger, multi-center studies with longer follow-up durations and subgroup analyses based on GMFCS levels and CP subtypes are also recommended. Such work would enhance generalizability, validate clinical thresholds, and contribute to the development of standardized guidelines for motor outcome monitoring in children with CP.

Declaration by Authors

Ethical Approval: Approved

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