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UPPER LIMB MOVEMENT VARIABILITY AND TASK PERFORMANCE IN DYSKINETIC CEREBRAL PALSY: AN INSTRUMENTED KINEMATIC ANALYSIS

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ABSTRACT

Upper limb function is significantly impacted by the aimless, erratic movements associated with dyskinetic cerebral palsy (DCP). The need for objective, instrumented evaluation techniques is demonstrated by the clinical assessment scales' weak sensitivity to movement variability and task execution characteristics. Using instrumented motion analysis, upper limb motion variability, task length, and joint kinematics during functional reach tasks were described for people with dyskinetic cerebral palsy in comparison to their peers without disabilities. Three standardized upper limb activities were completed by subjects with DCD and the same age usually developing comparison group: reach forward, reach laterally, and reach-to-grasp vertically. Upper limb kinematics were assessed using three-dimensional optometric motion capture, and segmental angular velocity was obtained using inertial measurement units. The coefficient of multiple correlations for between-trial comparisons was used to assess movement variability. To identify motor control techniques, the task's duration and joint angles upon task completion were analyzed. Across all activities, persons with DCP had considerably more movement variability than those with usual development. In the DCP group, task completion joint locations varied, especially at the wrist and elbow, and task time was longer. Distal tasks were the most variable. Clinical observation alone is unable to capture the unique movement characteristics of dyskinetic cerebral palsy, according to instrumented assessment. The importance of quantitative motion analysis for clinical assessment and intervention monitoring is demonstrated by increased variability, extended task execution, and modified joint strategies.

Keywords: *Dyskinetic cerebral palsy, upper limb, movement variability, kinematics, inertial sensors*

INTRODUCTION

A non-progressive neurodevelopmental condition, cerebral palsy (CP) is defined by ongoing abnormalities in posture and movement brought on by injuries in the developing brain (Blair, Cans, & Sellier, 2025). Among the several clinical subtypes, dyskinetic CP is characterized by decreased selective motor control, variable muscle tone, and involuntary movements that significantly impede functional motor performance. It is believed that the main cause of these motor deficits is malfunction in the basal ganglia–thalamocortical circuits, which results in decreased movement consistency, increased neural noise, and altered motor planning (Haberfehlner et al., 2020).

Recent biomechanical and neurophysiological studies have highlighted that impaired neuromuscular coordination and increased movement variability, especially during goal-directed activities, are more important explanations for motor dysfunction in CP than muscle weakening alone (Bonanno et al., 2025). Exaggerated joint excursions, poor inter-joint coordination, and trouble controlling movement time, particularly in distal segments, are all signs of dyskinetic CP, according to kinematic and motor control research. Detailed kinematic investigations of upper-limb performance in dyskinetic CP populations have previously brought attention to the defective integration of sensory feedback with motor output, which is reflected in these abnormalities (Bekteshi et al., 2023).

A useful method for measuring these minute motor anomalies is instrumented motion analysis. Specifically, objective evaluation of joint-level control, inter-segmental coordination, and task-specific motor strategies is made possible by multi-segment kinematic assessment (Adjel, 2024). Previous studies on CP have demonstrated that variation in joint kinematics is a significant indicator of defective motor control, revealing underlying brain dysfunction rather than just peripheral mechanical limitations, and is not just a source of measurement error (Zhang et al., 2022).

There are still very few investigations that combine clinically significant interpretations of motor impairment in dyskinetic CP with task-dependent kinematic behavior. Moreover, few studies have directly connected observed kinematic variability to possible neuromotor dysfunction mechanisms and the significance of rehabilitation (Dar, Stewart, McIntyre, & Paget, 2024). With a focus on joint-level behavior, movement variability, and their implications for functional motor control and rehabilitation techniques, the current study aimed to expand on previous CP kinematic research by investigating (Gascon, Maldonado Numata, Emond, Nemanich, & Robert, 2025).

This study used an instrumented assessment technique to examine upper limb movement variability, task length, and joint kinematics between people with dyskinetic cerebral palsy and normally developing adults. We predicted that individuals with DCP would show longer task durations, more movement variability, and different joint configurations when completing tasks.

2. Methods

2.1 Participants

Both usually developing controls and people with a clinical diagnosis of dyskinetic cerebral palsy were enlisted. A verified diagnosis of dystonia and/or choreoathetosis and the capacity to complete the reaching activities on one's own were prerequisites for inclusion in the DCP group. Individuals who had recently undergone surgery or medication that affected their motor function were not allowed to participate. In compliance with institutional ethical rules, each subject gave informed consent.

2.2 Experimental Tasks

Three conventional upper limb exercises were completed by the participants: (1) reaching forward, (2) reaching sideways, and (3) reach-to-grasp vertically. The tasks were chosen to test proximal and distal motor control as well as to cause the involuntary motions that are frequently seen in DCP.

2.3 Instrumentation

A three-dimensional optometric motion capture device was used to record upper limb kinematics.

In accordance with established methods, reflective markers were applied to anatomical landmarks of the trunk and upper limb segments (Jaspers et al., 2011). To record angular velocity signals in sync with motion capture data, inertial measurement units were affixed to upper limb segments.

2.4 Data Processing

From the beginning of a task to the point of task achievement (PTA), movement cycles were identified. The wrist, elbow, and shoulder joint angles were computed. Time-normalization and filtering were applied to angular velocity signals. The total time needed to finish each movement cycle was used to compute the task length.

2.5 Outcome Measures

Primary outcome measures included: Movement variability, quantified using the coefficient of multiple correlation (CMC) across repeated trials.
Task duration, expressed in seconds.
Joint angles at PTA, representing movement strategy at task completion.

2.6 Statistical Analysis

Group differences between participants with DCP and typically developing controls were assessed using non-parametric statistical tests due to non-normal data distribution. Descriptive statistics were used to summarize variability and kinematic measures across tasks.

3. Results

3.1 Movement Variability

Participants with dyskinetic cerebral palsy demonstrated substantially increased movement variability across all tasks compared with typically developing participants.

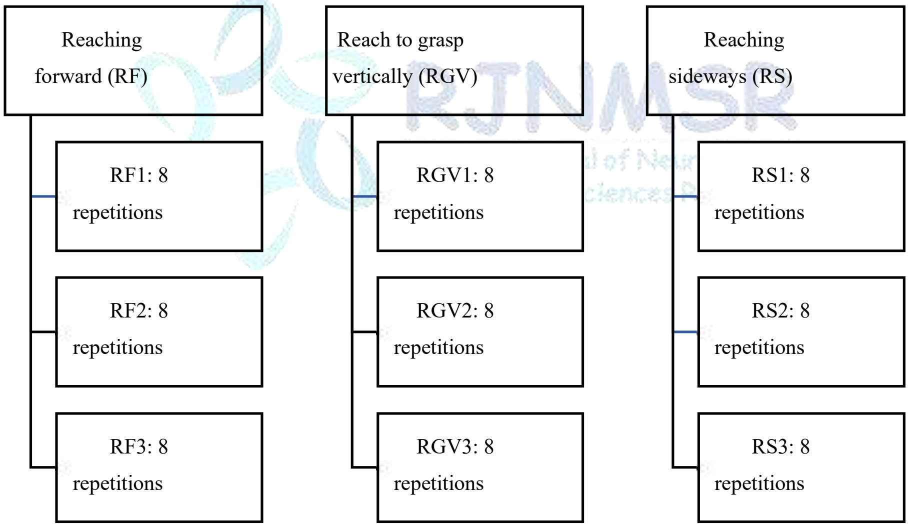

Figure 1. Representative elbow flexion–extension waveforms across repeated trials in a participant with DCP and a typically developing participant, illustrating increased variability in DCP.

CMC values were lowest during the reach-to-grasp task, indicating greater inconsistency when distal control demands increased.

3.2 Task Duration

Task duration was significantly longer in the DCP group for all tasks.

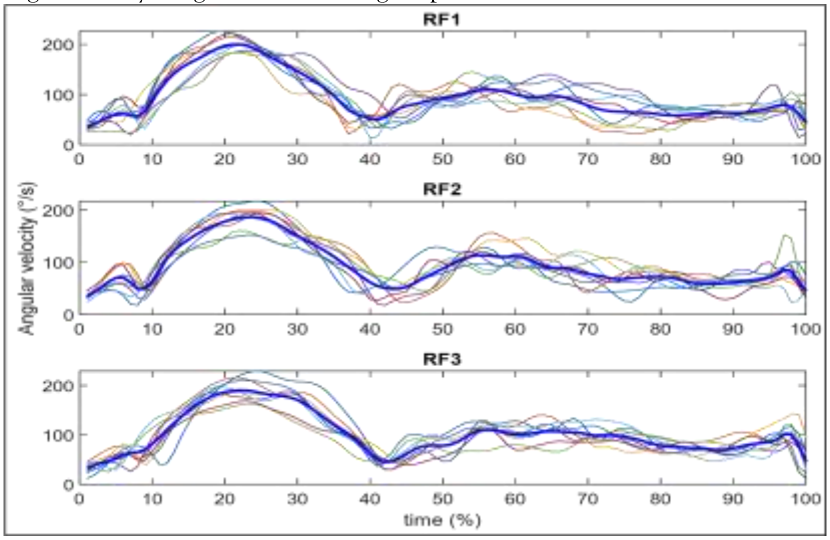

Figure 2. Mean task duration (±SD) for each task in participants with DCP and typically developing controls.

Prolonged task execution reflected difficulties in movement initiation, control, and termination.

3.3 Joint Angles at Point of Task Achievement

Altered joint configurations at PTA were observed in participants with DCP, particularly at the elbow and wrist. Increased wrist flexion and reduced elbow extension were commonly observed during task completion.

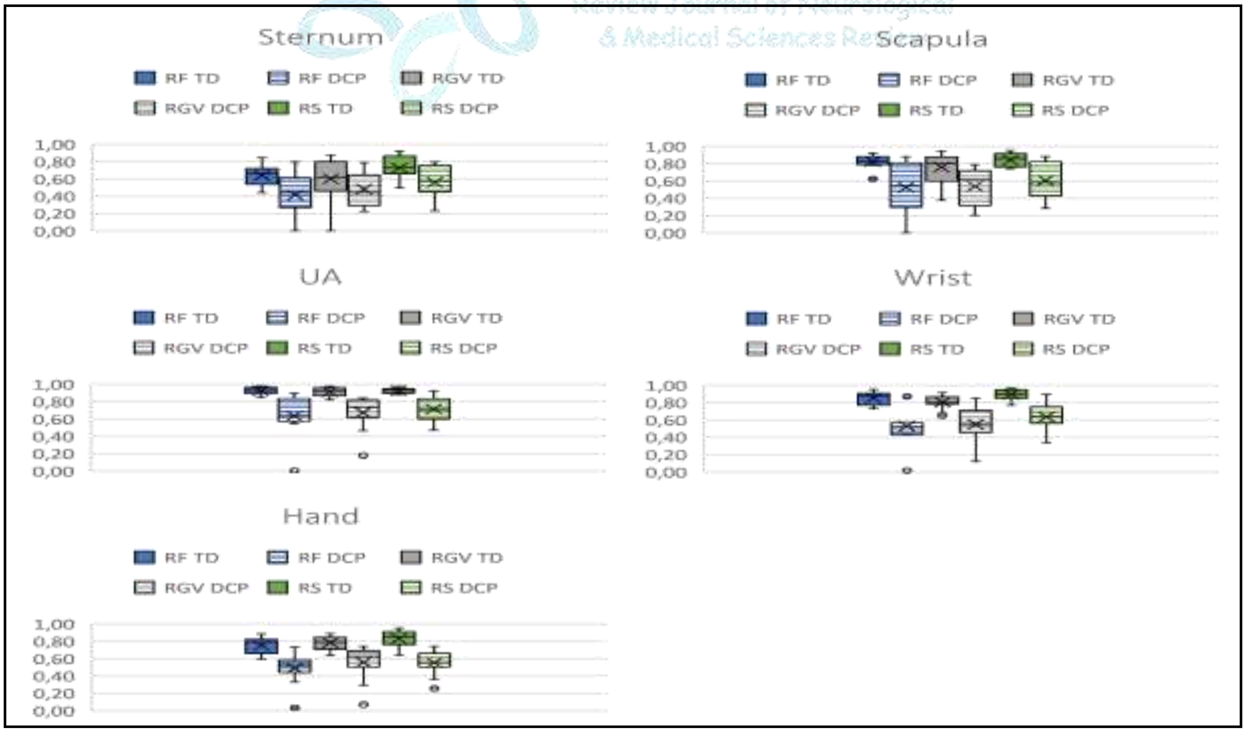

Figure 3. Comparison of joint angles at the point of task achievement between groups.

Fig. 3 Variability of angular velocity waveforms of typically developing (TD) children and children with dyskinetic cerebral palsy (DCP) during reaching forward (RF), reach to grasp vertically (RGV) and reaching sideways (RS).

Discussion

This study demonstrates clear differences in upper limb movement characteristics between individuals with dyskinetic cerebral palsy and typically developing participants. Increased movement variability across all tasks confirms previous observations that dyskinetic movements are inherently inconsistent and task-dependent. The idea that dyskinetic CP is characterized by poor control of motor output rather than a permanent movement deficiency is supported by the increased variability (Vanmechelen et al., 2024). This is consistent with earlier research showing that malfunction of the basal ganglia causes excessive motor command fluctuations, diminished inhibitory control, and trouble regulating involuntary muscle activity (Stevens, 2024). The uneven joint trajectories and timing abnormalities found in the current investigation are probably caused by these mechanisms.

Crucially, these results support the idea that movement variability in dyskinetic CP is not just compensatory behavior or measurement noise, but rather a pathophysiological characteristic of poor neuromotor control (Vanmechelen et al., 2024). Higher-level motor planning and sensory integration processes may be especially impacted, as previous kinematic studies in CP populations have shown that variability rises with task complexity and precision demands (Gascon et al., 2025). The recent findings add to this knowledge by showing that the importance of quantitative motion analysis for clinical assessment and intervention monitoring is demonstrated by increased variability, extended task execution, and modified joint strategies.

The current findings have significant clinical ramifications for rehabilitation. Strength and range of motion are frequently given priority in traditional therapies, but the patterns shown suggest that motor coordination, movement consistency, and task-specific control should also be included in rehabilitation techniques (Vanmechelen et al., 2022). The underlying brain mechanisms causing dyskinetic movement patterns may be better addressed by interventions that include technology-assisted training, sensory feedback improvement, and repetitive task repetition (Giannoni, 2022).

There are certain limitations acknowledged. Although the kinematic measures provide objective insight into motor behavior, they do not directly quantify neural drive or muscle activation patterns. Future studies integrating kinematic analysis with surface or high-density electromyography may further elucidate the relationship between neural control deficits and observed movement variability. Nonetheless, the present study contributes to a growing body of evidence supporting the use of advanced kinematic assessment to improve both the understanding and clinical management of motor dysfunction in dyskinetic CP.

Conclusion

In dyskinetic cerebral palsy, different upper limb movement patterns are shown by instrumented kinematic assessment. These patterns are marked by greater variability, longer task length, and changed joint strategies. These quantitative measurements complement the use of instrumented methods for clinical evaluation and intervention monitoring and offer useful information beyond clinical observation.

Authors' contributions:

1 and 2 wrote the introduction and methodology.
1 and 4 wrote the manuscript.
1, 4, 5 and 6 carried out the study selection and data extraction and analysis.
1, 2 and 3 conceived the original idea.
2 and 6 supervised the project.

References

Adjel, M. (2024). Toward the development of a sparse, multi-modal and affordable motion analysis system. Applications to clinical motor tests. Université de Paris-Est/Créteil.

Bekteshi, S., Monbaliu, E., McIntyre, S., Saloojee, G., Hilberink, S. R., Tatishvili, N., & Dan, B. (2023). Towards functional improvement of motor disorders associated with cerebral palsy. The Lancet Neurology, 22(3), 229-243.

Blair, E., Cans, C., & Sellier, E. (2025). Epidemiology of the cerebral palsies. Cerebral Palsy: From Childhood to Adulthood, 27-38.

Bonanno, M., De Pasquale, P., Fonti, B., Gjonaj, E., De Salvo, S., Quartarone, A., & Calabrò, R. S. (2025). Neural control meets biomechanics in the motor assessment of neurological disorders: a narrative review. Frontiers in Neural Circuits, 19, 1608328.

Dar, H., Stewart, K., McIntyre, S., & Paget, S. (2024). Multiple motor disorders in cerebral palsy. Developmental Medicine & Child Neurology, 66(3), 317-325.

Gascon, H. D., Maldonado Numata, S. A., Emond, S., Nemanich, S., & Robert, M. T. (2025). Age-related differences in behavioral outcomes of bimanual functional motor tasks in children and adolescents with cerebral palsy: a scoping review. Disability and Rehabilitation, 47(15), 3781-3793.

Giannoni, P. (2022). Rehabilitation technologies for sensory-motor-cognitive impairments Cerebral Palsy: A Practical Guide for Rehabilitation Professionals (pp. 461-511): Springer.

Haberfehlner, H., Goudriaan, M., Bonouvrié, L. A., Jansma, E. P., Harlaar, J., Vermeulen, R. J., . . . Buizer, A. I. (2020). Instrumented assessment of motor function in dyskinetic cerebral palsy: a systematic review. Journal of neuroengineering and rehabilitation, 17(1), 39.

Jaspers, E., Desloovere, K., Bruyninckx, H., Klingels, K., Molenaers, G., Aertbeliën, E., . . . Feys, H. (2011). Three-dimensional upper limb movement characteristics in children with hemiplegic cerebral palsy and typically developing children. Research in developmental disabilities, 32(6), 2283-2294.

Stevens, A. (2024). Lentiform Nucleus Damage in Motivational Deficits in Dyskinetic Cerebral Palsy: A Work in Progress.

Vanmechelen, I., Bekteshi, S., Konings, M., Feys, H., Desloovere, K., Aerts, J.-M., & Monbaliu, E. (2022). Psychometric properties of upper limb kinematics during functional tasks in children and adolescents with dyskinetic cerebral palsy. PLoS One, 17(9), e0266294.

Vanmechelen, I., Desloovere, K., Haberfehlner, H., Martens, B., Vermeulen, J. R., Buizer, A. I., . . . Monbaliu, E. (2024). Altered upper limb kinematics in individuals with dyskinetic cerebral palsy in comparison with typically developing peers–A statistical parametric mapping study. Gait & Posture, 107, 141-151.

Zhang, L., Deng, C. F., Liu, Y., Chen, L., Xiao, N., Zhai, S. J., . . . Wu, X. Y. (2022). Impacts of motor developmental delay on the inter-joint coordination using kinematic synergies of joint angles during infant crawling. IEEE Transactions on Neural Systems and Rehabilitation Engineering, 30, 1664-1674.