ORIGINAL ARTICLE

Physical Therapy Journal of Indonesia (*PTJI*) 2025, Volume 6, Number 1: 83-87
E-ISSN : 2722-6034 ; P-ISSN : 2722-0125

The effect of non-invasive treatment based on neurodevelopmental treatment on trunk control and upper extremity functional ability in children with spastic diplegia cerebral palsy

Aditya Denny Pratama[1*], Hana Hasyim[1], Marilyn Moffat[2]

ABSTRACT

Background: Children with spastic diplegia cerebral palsy often showed impaired trunk control and upper limb function, which limited their daily activities and independence. Neurodevelopmental treatment (NDT) was used as a physiotherapy approach to improve motor control and reduce abnormal muscle tone. However, the evidence on its effectiveness for upper limb function and trunk control remained limited. This study aimed to examine the effect of non-invasive treatment based on NDT on trunk control and upper extremity functional ability in children with spastic diplegia.

Methods: This pre-experimental one-group pre-test–post-test study involved 20 children aged 5–12 years with spastic diplegia cerebral palsy (gross motor gunction classification system (GMFCS) Level III) who received NDT-based physiotherapy twice a week for eight weeks at Yayasan Ramah Cerebral Palsy (RCP), Bogor. The study excluded children with spastic hemiplegia, quadriplegia, athetoid CP, comorbid conditions such as heart disease, non-active members, and those who did not undergo therapy at RCP. Researchers measured upper extremity function using the quality of upper extremity skills test (QUEST) and assessed trunk control using the trunk control measurement scale (TCMS). They analyzed the data using paired sample t-tests to compare pre- and post-intervention results and applied *Pearson's* correlation to examine the relationship between trunk control and upper limb function.

Results: Post-intervention evaluation revealed a significant improvement in upper extremity function (QUEST mean increase: 22.45±3.05, $p< 0.001$) and trunk control (TCMS mean increase: 16.15±5.01, $p< 0.001$). The relationship between improved trunk control and enhanced upper extremity function was significant, as indicated by *Pearson's* correlation of 0.696, $p < 0.001$.

Conclusion: In children diagnosed with spastic diplegia CP, an 8-week NDT intervention significantly improved upper extremity functional capacity and trunk control. The findings emphasized that the application of NDT in enhancing motor coordination and independence, thereby contributing to an improved quality of life for this population.

Keywords: cerebral palsy, children, functional mobility, neurodevelopmental treatment, trunk control, upper extremity.

Cite This Article: Pratama, A.D., Hasyim, H., Moffat, M. 2025.The effect of non-invasive treatment based on neurodevelopmental treatment on trunk control and upper extremity functional ability in children with spastic diplegia cerebral palsy. *Physical Therapy Journal of Indonesia* 6(1): 83-87. DOI: 10.51559/ptji.v6i1.271

[1]Physiotherapy Department, Vocational Education Program, Universitas Indonesia, Depok, West Java, Indonesia;
[2]Doctor of Physical Therapy Program, Steinhardt School of Culture, Education and Human Development, New York University, United States.

*Corresponding author:
Aditya Denny Pratama;
Vocational Education Program, Universitas Indonesia, Depok, West Java, 16424, Indonesia;
pratama.aditya@ui.ac.id

Received: 2025-02-05
Accepted: 2025-05-07
Published: 2025-06-05

INTRODUCTION

Cerebral palsy (CP) is a developmental disorder that results from brain injury occurring during early childhood.[1] The global incidence of CP ranges from 1.5 to 3 per 1.000 live births, affecting both developed and developing countries across various geographical regions.[2] Neuromotor dysfunction is typically recognized within the first year of a child's life, with the period between ages 2 to 5 being critical for the manifestation of CP symptoms.[3] In Indonesia, the prevalence of developmental anomalies in children including delays in physical, cognitive, and sensory abilities is notably high. According to the 2023 Indonesian Health Survey, 863,402 cases of children were reported to have mental, physical, and sensory developmental impairments.[4]

West Java Province recorded the highest incidence of developmental delays, with 154,472 reported cases and a CP prevalence rate of 0.1%. Furthermore, the province documented 33.565 cases of physical, intellectual, mental, sensory, and communication disabilities among children aged 5 to 17, with a physical disability prevalence of 0.5%.[4] CP is a neurological condition that may occur due to brain damage before or after birth.[5] Its common sensorimotor manifestations include reduced postural control, abnormal muscle tone, and both gross and fine motor impairments. CP can also affect cognitive and intellectual abilities.[6]

Children with CP often show signs such as postural abnormalities, which stem from damage to the brain's pyramidal tract a pathway responsible for controlling movement, cognition, and sensation.[7,8] This tract originates in the cerebral cortex.[9] Lesions in this area impair a child's ability to manage movements, thereby reducing their independence.[10] As explained by Heide and Algra in Biyik (2024), children with CP experience difficulties in controlling posture and muscle contractions required for upper limb movements. They tend to exhibit excessive co-activation of antagonist muscles and struggle with head control during trunk postural tasks.[11] This dysfunction poses significant barriers to their ability to perform daily activities independently and requires further investigation.[12] The inability to regulate posture significantly affects the functional use of their upper limbs.[13]

A study conducted in Java and Sumatra islands assessed the independence levels of children with CP. In Bogor City, 10 out of 33 children with CP were classified at GMFCS levels III or IV. Spastic CP was the most prevalent type (70%), followed by athetoid CP (15%).[14] These findings suggest the need for further research on the relationship between trunk control and upper limb functional capacity in children with CP, particularly in their ability to carry out daily activities independently.

As children grow and develop, diminished functional abilities especially those affecting independence in daily tasks must be addressed. Physiotherapy plays a crucial role in supporting the educational and developmental needs of these children.[15] According to the World Confederation for Physical Therapy, physiotherapy contributes to rehabilitation and curative care across all stages of life.[16] One commonly used method in pediatric physiotherapy is neurodevelopmental treatment (NDT).[17] NDT is based on advances in neuroscience and aims to improve neuromotor and postural control in children with CP. It focuses on the physiology of neural structures and cerebral tissue. Scientific evidence has demonstrated the effectiveness of NDT in improving gross motor skills among Indonesian children with CP.[18] For example, a previous study showed significant improvement in gross motor abilities after four weeks of NDT (twice a week for 60 minutes per session).[19]

However, there is limited research on the effects of NDT on trunk control and upper limb function in children with CP in South East Asia, especially within the Indonesia. Therefore, the current study aimed to investigate the impact of NDT on trunk control and upper limb functional ability in children with CP. This study hypothesized that NDT interventions significantly improve trunk control and have a positive effect on upper limb functional capacity. In addition, it also aimed to explore the correlation between enhanced trunk control and improved upper limb function following NDT in children with CP.

METHODS

This research used a quantitative approach with a pre-experimental design, a one-group pre-test-post-test method.[20] The intervention was carried out over eight weeks, with two sessions per week, each lasting 60 minutes. The independent variable in this study is NDT, while the dependent variables are trunk control and upper extremity functional ability. The intervention was conducted by the professional physiotherapists for children with cerebral palsy who undergoing therapy at pediatric physiotherapy center of Yayasan Ramah Cerebral Palsy (RCP) Bogor, Indonesia. Data collection took place over two months, from February to March 2025.

The sample size was determined of 20 children with cerebral palsy who were active members receiving therapy at RCP Bogor, Indonesia using G-power application. Inclusion criteria were children aged 5 to 12 years diagnosed with cerebral palsy with classification of gross motor function classification system (GMFCS) levels III to IV. Exclusion criteria included children with spastic hemiplegia, quadriplegia, athetoid cerebral palsy, those with comorbid conditions such as heart disease, and those not actively undergoing therapy at RCP Bogor, Indonesia. Participants who met the inclusion criteria provided informed consent after receiving information about the benefits, procedures, and potential risks of the intervention. Sampling was conducted using a purposive sampling technique, which is a non-probability method based on specific criteria rather than random selection.[21] This approach was chosen to improve internal validity and facilitate relevant clinical application of the intervention.

The trunk control measurement scale (TCMS) was used to measure trunk control. This scale evaluates postural control in three domains: static sitting balance, dynamic sitting balance, and dynamic reaching ability, with a total possible score ranging from 0 to 58.[22,23] For assessing upper extremity function, the quality of upper extremity skills test (QUEST) was applied. QUEST is designed to assess movement patterns and functional abilities of the upper limbs in children with cerebral palsy and consists of 34 items divided into three domains of hand function, spasticity, and cooperation.[24]

During the QUEST assessment, children were seated on a chair without armrests or a backrest to ensure standardized positioning, with support provided as needed. The scoring system assigns a score of one if the child is unable to complete the task and a score of two if the child performs the movement successfully. In this study, the evaluation was based on the child's ability to follow instructions and complete the required movements.

This study recruited the 24 and 36 children with cerebral palsy to test the instrument validity of TCMS and QUEST, respectively. In addition, the gender and age distribution of the research subjects were analyzed using SPSS version 27. Descriptive statistical analysis was utilized to summarize the data. The internal consistency of TCMS and QUEST were measured. The study hypotheses were tested using the paired sample t-test to evaluate the significant effect of the independent variable on the dependent variables. Additionally, the *Pearson's* correlation test was applied to examine the relationship between the independent and dependent variables.

RESULTS

Out of the 20 children, 11 (55%) were male, and 9 (45%) were female, indicating a slightly higher representation of males. Most of the boys at the RCP Bogor, Indonesia were diagnosed with spastic diplegia, a common form of cerebral palsy. The average age of the subjects was 7 years and 9 months. The largest numbers of age group was 5-6 years old (50%) of the

Table 1. Frequency distribution of characteristics of research subjects based on gender, age, and gross motor classification

Characteristic	Frequency	Percentage
Gender		
Male	11	55%
Female	9	45%
Age		
5-6 years	10	50%
7-8 years	2	10%
9-10 years	1	5%
11-12 years	7	35%
GMFCS		
Level III	20	100%

GMFCS, gross motor functional classification system

Table 2. Analysis of data distribution for assessing the validity and reliability of TCMS and QUEST examination instruments

Measure	Cronbach's Alpha	N of items	*P*-value
TCMS	0.935	24	<0.001
QUEST	0.945	36	<0.001

QUEST, the quality of upper extremity skills test; TCMS, trunk control measurement scale

Table 3. Distribution of significance of research subjects based on TCMS and QUEST values using Paired Sample *T*-test

Variable	Mean	*P*-value
TCMS		
Pre-test	26.75±3.11	<0.001
Post-test	42.90 8.12	<0.001
QUEST		
Pre-test	25.40 3.70	<0.001
Post-test	47.85 6.75	<0.001

QUEST, the quality of upper extremity skills test; TCMS, trunk control measurement scale

Table 4. Distribution of correlation of research subjects based on TCMS and QUEST values Pearson's Correlation

Variable	Mean	*P*-value
TCMS	0.696	<0.001
QUEST	0.696	<0.001

QUEST, the quality of upper extremity skills test; TCMS, trunk control measurement scale

participants, followed by the 11–12 years old group (35%). The 7–8 and 9–10 years old groups were accounted for 10% and 5% of the participants, respectively. The detailed characteristics of the subjects are presented in Table 1.

Table 2 showed the results of validity score of TCMS and QUEST. All items on the TCMS showed the *Cronbach's* alpha was 0.935, indicating high internal consistency with *p*-value < 0.050. Similarly, QUEST had a *Cronbach's* alpha of 0.945, *p*-value< 0.050, which representing the high internal consistency.

The paired sample T-test results demonstrated a significant effect of NDT on trunk control, with a mean difference and standard deviation of 16.15±5.01 and *p*-value< 0.001. Similarly, NDT showed a significant impact on upper extremity functional ability, with mean difference ± standard deviation of 22.45 ± 3.05 and *p*< 0.001 (Table 3). Furthermore, a strong positive correlation was found between NDT intervention for trunk control and upper limb functional capacity *r*= 0.696, *p* < 0.001 (Table 4).

DISCUSSION

The findings of this study showed that most children were of school-going age and require a considerable level of motor coordination to effectively perform daily activities. Therefore, coordination, balance, and stability are critical factors that support children's functional independence. School-age children who have generally developed awareness of functional motor activities are more capable of communicating and actively participating in physiotherapy sessions. Children within this developmental stage are appropriate candidates for structured and targeted NDT interventions.[17] This approach requires the child's active involvement in exercises to stimulate body awareness and enhance motor control and planning.[25] Moreover, the majority of participants had reached a more advanced stage of motor development, indicating increased maturity. At this developmental stage, adequate trunk control is essential to support upper limb activities such as reaching and grasping. Thus, selecting school-aged children as subjects is relevant and appropriate to investigate the effect of NDT on trunk control and upper limb functional ability in children with cerebral palsy. All subjects were classified as GMFCS level III, indicating that while they required assistive devices for mobility, they were able to move independently using such tools.[14] Some subjects used wheelchairs operated independently for mobility purposes.

Children classified as GMFCS Level III are able to perform functional mobility with the assistance of devices such as walkers, crutches, or independently operated wheelchairs. In the context of this study, all participants were categorized as GMFCS Level III, indicating that they could mobilize using assistive devices, particularly independent wheelchairs, in carrying out daily activities. Some were able to control these devices effectively in terms of direction and speed for short-distance mobility. The homogeneous selection of subjects at GMFCS Level III was based on previous research by Trisnowiyanto (2020), which identified 10 children at this functional level in Bogor City. Therefore, the researcher focused on evaluating the effects of NDT on trunk control and upper limb functional capacity in children with cerebral palsy at GMFCS Level III.[14]

After eight weeks of NDT intervention, researchers observed improvements in postural trunk control. The facilitation technique, as proposed in the Bobath concept of NDT, promotes essential and purposeful motor patterns through a learning process that modifies functional tasks to encourage normalized movement.[26] Improving trunk control was achieved by activating core muscles such as the erector spinae, gluteus medius, rectus abdominis, and multifidus. While GMFCS Level III subjects had limited mobility, their ability to move independently reflected a degree of autonomy. However, they often displayed abnormal postural alignment due to compensatory spasticity and motor planning deficits.

The NDT intervention applied over eight weeks aimed to reduce spasticity through active-assisted isometric pelvic exercises and to facilitate muscle activation using functional tasks. These included sitting on a bolster while performing reaching activities, such as placing a ball in a basket, reaching for overhead toys, or transitioning from sitting to standing while handling a ball. These exercises were shown to activate postural muscles, aligning with findings by Paludo et al. (2023), who found that similar tasks activated the gluteus medius and multifidus through electromyography (EMG) studies.[27] In the current study, functional activities that incorporated sit-to-stand transitions and active reaching were found to engage the gluteus medius and rectus abdominis, supporting postural control and improving movement coordination. Repetition of such activities contributes to neuroplasticity and strengthens the muscle activation pathways.

These findings are consistent with research by Park et al. (2023), who demonstrated that NDT improves static and dynamic trunk control in children with cerebral palsy. Their methodology involved facilitation techniques targeting agonist and antagonist trunk muscles, enhancing postural quality and lumbar stability.[28] Measurement using the TCMS showed a significant post-intervention improvement, indicating that NDT had a positive effect on trunk control. Numerical increases in pre-test and post-test scores further supported the efficacy of the intervention.

The QUEST results also showed enhanced upper limb function following the NDT intervention. This improvement resulted from functional training techniques focused on trunk muscle activation and spasticity reduction. Interventions included coordination training of eye, head, and neck movements and facilitation of trunk muscle engagement, followed by active elongation exercises involving reaching movements. A notable finding was the presence of compensatory elbow movements due to inadequate trunk stabilization, which impaired upper limb function. This aligns with research by Bagesterio et al. (2023), which showed that children with cerebral palsy require more time and distance to perform reaching tasks due to inefficient motion control and compensatory strategies in the shoulders and elbows.[29]

During the intervention, children were positioned upright, with the head neutral and eyes looking forward. They were instructed to use their dominant hand to retrieve a ball placed diagonally across their body and deposit it into a basket. This task was performed over eight weeks in progressive stages. The intervention encouraged coordination across the eyes, head, trunk, and hands, improving motor planning. Observations indicated that when children used the more affected side, deviations were more pronounced, largely due to spasticity and reduced ability to regulate motion. Many exhibited exaggerated or jerky movements and were unable to terminate actions smoothly, leading to variability in performance.

When presented with a toy at eye level, children often reached for it with compensatory patterns, such as shoulder depression or elbow rotation. These movements suggest absent or impaired reticulospinal input. In most cases, poor upper limb control stemmed from insufficient trunk support, as confirmed by Sanya et al. (2022), who linked inadequate triceps control to compromised upper trunk function and poor postural control.[30] These findings affirm that poor postural control in children with cerebral palsy limits balance and motor function.

Somatosensory deficits further exacerbate compensatory movement patterns, impacting learning capacity. GMFCS level III children struggle particularly with higher-level postures, such as standing and supination.[29,31,32] The study revealed a significant, positive correlation between trunk control and upper limb function post-intervention, confirming the research hypothesis. Increased TCMS post-test scores suggest that NDT consistently enhances trunk control by promoting functional movement patterns. Exercises that focus on active sitting, standing transitions, and core strengthening were shown to improve balance and postural coordination.

The QUEST results indicated improvements in both gross and fine motor skills. Functional reaching exercises, performed in seated positions with rotation and elongation components, stimulated trunk muscle engagement and improved upper limb coordination. NDT facilitation techniques enabled better postural control, reduced compensations, and improved motor planning.

These results illustrate the central role of trunk control in optimizing upper limb function. Strengthening core stability leads to better execution and control of purposeful movements. This study supports the conclusion that effective trunk stabilization is fundamental for developing fine and gross motor skills in children with cerebral palsy.

Nevertheless, the study has several limitations. The sample was limited to children with spastic diplegia, without a control group for comparison. All participants were at GMFCS Level III, limiting generalizability to more severe cases. The intervention duration was only eight weeks, with no follow-up evaluation after one month to determine long-term effects.

CONCLUSION

The findings of this study demonstrate that an eight-week NDT program significantly improved trunk control and upper extremity functional ability in children with spastic diplegic cerebral palsy classified at GMFCS Level III. The intervention led to notable enhancements in trunk stability and coordination of upper limb movements, as evidenced by increased scores on both the TCMS and QUEST assessments, reflecting improved posture and functional performance.

These results reinforce the effectiveness of NDT in facilitating motor control and functional independence in children with cerebral palsy. The observed improvements underscore the critical role of targeted physiotherapy interventions, such as NDT, in optimizing postural control, which in turn positively impacts upper limb function. Enhancing trunk control enables more efficient engagement in daily activities and promotes greater autonomy. Therefore, this study supports the integration of NDT into routine rehabilitation programs for children with mild motor impairments, aiming to improve motor planning, postural stability, and overall functional capabilities.

ETHICAL CLEARANCE

Universitas Indonesia research ethics commission has approved this research and deemed it ethically feasible, as indicated by letter number KET-47/UN.2F14/KEPV/PPM.00.002/2025.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest that could have influenced the conduct or outcomes of this research.

FUNDING

This research received no specific grant from any funding agency in the public, commercial, or non-profit sectors

AUTHOR CONTRIBUTIONS

ADP and HH designed the study methodology, collected and analyzed the data, conducted the literature review, and prepared the initial manuscript. ADP and MM reviewed and edited the final version of the manuscript.

REFERENCES

1. Patel DR, Neelakantan M, Pandher K, Merrick J. Cerebral palsy in children: A clinical overview. Transl Pediatr. 2020;9(1):S125–35.
2. Likhar A, Baghel P, Patil M. Early Childhood Development and Social Determinants. Cureus. 2022;14(9):e28913.
3. Lidbeck C, Bartonek Å. Motor function at increasing postural demands in children with bilateral cerebral palsy. Eur J Phys Rehabil Med. 2021;57(5):731–7.
4. BKPK K. Survey Kesehatan Indonesia Tahun 2023 Dalam Angka. Survey Kesehatan Indonesia (SKI) 2023. Jakarta: Kementrian Kesehatan Badan Kebijakan Pembangunan Kesehatan Indonesia; 2023. p. 284–95.
5. Carlsen H, Vik T, Andersen GL, Stangenes K, Bjellmo S, Westvik-Johari K, et al. Cerebral palsy in children born after assisted reproductive technology in Norway: Risk, prevalence, and clinical characteristics. Acta Obstet Gynecol Scand. 2023;102(11):1450–8.
6. Te Velde A, Morgan C, Novak I, Tantsis E, Badawi N. Early diagnosis and classification of cerebral palsy: An historical perspective and barriers to an early diagnosis. J Clin Med. 2019;8(10):1509.
7. Al-Nemr A. Synergistic effect of functional strength training and cognitive intervention on gross motor function in children with cerebral palsy. Appl Neuropsychol Child. 2024;13(3):246–55.
8. Chiu HC, Ada L, Cherng RJ, Chen C. Relative contribution of sensory and motor impairments to mobility limitations in children with cerebral palsy: an observational study. Sci Rep. 2023;13(1):14890.
9. Sadowska M, Sarecka-Hujar B, Kopyta I. Analysis of selected risk factors depending on the type of cerebral palsy. Brain Sci. 2021;11(11):1463.
10. Cristofori I, Cohen-Zimerman S, Grafman J. Executive functions. In: Handbook of Clinical Neurology. Vol 163. Elsevier; 2019. p. 197–219.
11. Vanmechelen I, Haberfehlner H, Martens BHM, Vermeulen RJ, Buizer AI, Desloovere K, et al. The relationship between manual ability, dystonia, choreoathetosis severity and upper limb movement patterns during reaching and grasping in children and young adults with dyskinetic cerebral palsy. Eur J Paediatr Neurol. 2024;50:41–50.
12. Seyhan-Bıyık K, Erdem S, Günel MK. The effects of postural control and upper extremity functional capacity on functional independence in preschool-age children with spastic cerebral palsy: a path model. Physiother Theory Pract. 2024;40(5):1054–63.
13. Jackman M, Sakzewski L, Morgan C, Novak I, Fahey M, Dark L, et al. Interventions to improve physical function for children and young people with cerebral palsy: international clinical practice guideline. Dev Med Child Neurol. 2022;64(5):536–49.
14. Trisnowiyanto B, Utomo B. The level of children's independence with cerebral palsy in several regions in Java and Sumatra. J Keterap Fisik. 2020;5(1):1–12.
15. Krishnaprasad KM, Narayan A, Kumar KV. Association between postural stability and functional abilities in children with spastic cerebral palsy. Crit Rev Phys Rehabil Med. 2022;34:67–75.
16. Yulizawati AR. Pertumbuhan dan Perkembangan Bayi. Sidoarjo: Indomedia Pustaka; 2018. p. 51.
17. Tekin F, Kavlak E, Cavlak U, Altug F. Effectiveness of Neuro-Developmental Treatment (Bobath Concept) on postural control and balance in cerebral palsied children. J Back Musculoskelet Rehabil. 2018;31(2):397–403.
18. Adiguzel H, Kirmaci ZIK, Gogremis M, Kirmaci YS, Dilber C, Berktas DT. The effect of proprioceptive neuromuscular facilitation on functional skills, muscle strength, and trunk control in children with cerebral palsy: A randomized controlled trial. Early Hum Dev. 2024;192:106010.
19. Putra MFA, Zaidah L. Pengaruh Bobath Neuro Development Treatment (NDT) terhadap kemampuan duduk pada penderita cerebral palsy usia 6 bulan sampai 12 tahun. Proc URECOL. 2020;235(3):16–20.
20. Agustina A, Ardhiani R. The influence of brain gym on changes in the numerical ability of grade I elementary students. Physical Therapy Journal Indonesia. 2023;4(2):219–21.
21. Adiputra IMS. Metodologi Penelitian Kesehatan. J GEEJ. 2020;7.
22. Kallem Seyyar G, Aras B, Aras O. Trunk control and functionality in children with spastic cerebral palsy. Dev Neurorehabil. 2019;22(2):120–5.
23. Talgeri AJ, Nayak A, Karnad SD, Jain P, Tedla JS, Reddy RS, et al. Effect of trunk targeted interventions on functional outcomes in children with cerebral palsy: A systematic review. Dev Neurorehabil. 2023;26(3):193–205.
24. Thorley M, Lannin N, Cusick A, Novak I, Boyd R. Reliability of the quality of upper extremity skills test for children with cerebral palsy aged 2 to 12 years. Phys Occup Ther Pediatr. 2012;32(1):4–21.
25. Arı G, Günel MK. A randomised controlled study to investigate effects of Bobath based trunk control training on motor function of children with spastic bilateral cerebral palsy. Int J Clin Med. 2017;8(4):205–15.
26. Almutairi A, Christy JB, Vogtle L. Vestibular and oculomotor function in children with cerebral palsy: A scoping review. Semin Hear. 2018;39(3):288–304.
27. Paludo T, Zardo F, De Mattos BTP, Frata B, Ling CC, De Castro Barroso G, et al. Measuring muscle activation using electromyography during neurodevelopmental treatment in individuals with severe cerebral palsy. J Back Musculoskelet Rehabil. 2023;36(3):691–700.
28. Park M, Kim J, Yu C, Lim H. The effects of neurodevelopmental treatment-based trunk control exercise on gross motor function and trunk control in children with developmental disabilities. Healthcare. 2023;11(10):1377.
29. Bagesteiro LB, Tellini TL, Brown LE. Analysis of motor characteristics of reaching movements in children with cerebral palsy. Heliyon. 2023;9(2)\:e13455.
30. Sanya A, Amitesh N, Krishnan S, Bolumbu G. Antagonistic asynchrony in biceps and triceps recruitment pattern during forward reach movement in children with cerebral palsy. Biomed. 2022;42(1):98–105.
31. Shekari Z, Sadeghian Afarani R, Fatorehchy S, Bakhshi E, Shahshahani S, Mousavi E. Relationship between postural asymmetry, balance, and pain in children with spastic cerebral palsy. Pediatr Neurol. 2024;155:84–90.
32. Benson K, Capone K, Duch K, Palmer-Casey C. Mobility supports in educational curriculum for children and youth with cerebral palsy. In: Cerebral Palsy. Springer; 2018. p. 1–14.