Received: December 20, 2024 / *Revised:* December 29, 2024 / *Accepted:* December 29, 2024

ORIGINAL ARTICLE

Journal of Hacettepe University
Physical Therapy and Rehabilitation

DIFFERENT TYPES OF ASYMMETRIC HAND INVOLVEMENTS AND FUNCTIONAL INDEPENDENCE IN CHILDREN WITH CEREBRAL PALSY: A RETROSPECTIVE STUDY

Kübra SEYHAN BIYIK*[1], Mintaze KEREM GÜNEL[1]

ABSTRACT

Purpose: The aim of this study was to investigate the effect of different types of functional asymmetric hand involvements on upper extremity activity performance and functional independence in children with cerebral palsy (CP).
Methods: In this retrospective study, 49 children with CP aged 3-12 years with different types of asymmetric functional hand involvements were analyzed. Asymmetric hand functions of the children were classified according to Bimanuel Fine Motor Function (BFMF-2.0). Upper extremity activity performance and functional independence status were evaluated with ABILHAND-Kids and Functional Independence Measure for Children (WeeFIM). The Kruskal-Wallis test was used for comparison between BFMF-2.0 levels.
Results: Children [7.18 ± 4.52 y (3-12 y), 26 girls (53.1%)] were divided into four groups as BFMF-2.0 level IIa (n=16), level IIIa (n=12), level IIIb (n=11) and IVb (n=10) according to functional asymmetric hand involvements. There was a significant difference between the groups ($p<0.001$). In pairwise comparisons, the difference between levels IVb and IIa was significant in WeeFIM and ABILHAND-Kids scores ($p<0.008$).
Discussion: In-hand manipulation skills are critical for upper extremity performance and functional independence of daily living activities in children with CP. In-hand manipulation of one hand may increase the functional independence of the child regardless of the other hand's involvement level.
Keywords: Hand, cerebral palsy, upper extremitiy, function, asymmetry

ÖZET

Amaç: Bu çalışmanın amacı, serebral palsili (SP) çocuklarda farklı tipte fonksiyonel asimetrik el tutulumlarının üst ekstremite aktivite performansı ve fonksiyonel bağımsızlık üzerine etkisini araştırmaktı.
Yöntem: Bu retrospektif çalışmada, farklı tipte fonksiyonel asimetrik el tutulumu olan 3-12 yaş arası 49 SP'li çocuk analiz edildi. Çocukların asimetrik el fonksiyonları Bimanuel İnce Motor Fonksiyon'a (BFMF-2.0) göre sınıflandırıldı. Üst ekstremite aktivite performansı ve fonksiyonel bağımsızlık durumu ABILHAND-Kids ve Çocuklar İçin Fonksiyonel Bağımsızlık Ölçüsü (WeeFIM) ile değerlendirildi. BFMF-2.0 seviyeleri arasındaki karşılaştırma için Kruskal-Wallis testi kullanıldı.
Sonuç: Çocuklar [7.18 ± 4.52 y (3-12 y), 26 kız (%53.1)] fonksiyonel asimetrik el tutulumlarına göre BFMF-2.0 seviye IIa (n=16), seviye IIIa (n=12), seviye IIIb (n=11) ve IVb (n=10) olmak üzere dört gruba ayrıldı. Gruplar arasında anlamlı bir fark vardı ($p<0.001$). Çiftler arası karşılaştırmalarda, WeeFIM ve ABILHAND-Kids skorlarında seviye IVb ve IIa arasındaki fark anlamlıydı ($p<0.008$).
Tartışma: SP'li çocuklarda el içi manipülasyon becerileri üst ekstremite performansı ve günlük yaşam aktivitelerinin fonksiyonel bağımsızlığı için kritik öneme sahiptir. Bir elin el içi manipülasyonu, diğer elin tutulum seviyesinden bağımsız olarak çocuğun fonksiyonel bağımsızlığını artırabilir.
Anahtar Kelimeler: El, serebral palsi, üst ekstremite, fonksiyon, asimetri

[1] Cerebral Palsy and Pediatric Rehabilitation Unit, Faculty of Physical Therapy and Rehabilitation, Hacettepe University, Ankara, Turkiye

*Corresponding author e-mail: kubra.seyhan@yahoo.com

INTRODUCTION

Functional skills such as grasping, holding, releasing, and manipulation of each hand may be affected at different levels due to varying degrees of muscle tone, joint movement, and selective motor control impairments in children with cerebral palsy (CP) (1). Most of daily living activities are bilateral and require functional use of both hands. Children with CP have difficulties with functional hand use in bimanual activities in daily living (2). Bimanual activities consist of symmetrical (both hands perform the same task simultaneously, e.g., picking up a large ball with both hands) and asymmetrical (both hands perform different parts of the task, e.g., using the fork and knife simultaneously for eating) tasks (3,4). Bimanual coordination of the upper extremities in an activity occurs with rhythmic, variable direction, sequential, and simultaneous movements of both hands (5,6).

In children with CP, the functional involvement of both hands may be asymmetric in bimanual activities (5,6). Although functional asymmetric upper extremity involvement is more prominent in children with unilateral CP (hemiplegia), children with bilateral CP (diplegia and quadriplegia) may also have different levels of functional asymmetric involvement such as in-hand manipulation, grasp, and hold (3,4). One hand can manipulate objects while the other hand can only grasp or hold the object (7). Moreover, daily living activities require various bilateral functional hand use, it is not clear how the different functional asymmetries between both hands affect upper extremity activities and functional independence in children with CP.

Children with functional asymmetric hand involvement use their affected hand more as an assistive or supporting hand while performing functional activities (8,9). Asymmetry becomes more apparent in bimanual activities that require complex selective motor control (8,9). Children may not be able to compensate for these activities with their hands and may need any assistance from another person to complete them. Asymmetric or symmetric hand use is likely to affect the performance of bimanual activities in different ways. For example, hand role differentiation may vary depending on the degree of hand use asymmetry (7,8). Additionally, functional asymmetric hand involvements during bimanual activities are evaluated via clinician outcome measures (Assisting Hand Assessment, Melbourne Assessment, and Shriners Hospital for Upper Extremity Evaluation etc.), parent-reported outcome measures (Pediatric Motor Activity Log and Children's Hand Use Experience), and classification systems (Zancolli and House Classifications), but these evaluations cannot classify or give any information about the severity of asymmetry during bilateral activity (10,11). The degree of asymmetry may also influence the choice of therapeutic interventions, such as constraint-induced movement therapy or intensive bimanual therapy (12,13). However, little is known about how children with CP, have functional asymmetric hand involvement, and use both hands together.

Considering these gaps in the literature, this study was conducted to investigate the effect of different types of functional asymmetric hand involvements on upper extremity activity performance and functional independence in children with CP. The hypotheses were 1) different asymmetric hand involvement would affect bimanual activity performance in children with CP, 2) different asymmetric hand involvement would affect functional independence in children with CP.

METHODS

This study is a retrospective cross-sectional study. It was conducted in Hacettepe University, Faculty of Physical Therapy and Rehabilitation, Cerebral Palsy and Pediatric Rehabilitaiton Unit. Approval for the study was obtained from Hacettepe University, Faculty of Physical Therapy and Rehabilitaiton Unit Research Ethics Committee (session date:19.09.2024, session number: 2024/19, decision number: FTREK24/35).

Participants

The study population consisted of children with CP who were admitted to Hacettepe University, Faculty of Physical Therapy and Rehabilitation, Cerebral Palsy and Paediatric Rehabilitation Unit with their parents. Children with spastic type, aged 3-12 years, who could follow the instruction, had visual ability, and had a functional asymmetric involvement of their hands, were retrospectively included in the study.

According to the inclusion criteria, the data generated between 01.01.2021 and 30.12.2023 were scanned retrospectively. During the screening of the files, children with another neurodevelopmental diagnosis (autism spectrum disorders, hydrocephalus, etc.) in addition to CP, orthopedic surgery, or neurotoxin administration in the upper extremities in the last six months were excluded from the study.

Measurements

Demographic data (age, gender, diagnosis, clinical type, etc.), functional levels, and upper extremity assessments were screened by a ten years-experienced physiotherapist in pediatric physiotherapy and rehabilitation.

Gross Motor Function Classification System (GMFCS): It is a valid and reliable functional classification developed by Palisano et al (14). It classifies the locomotor functions of children with CP at five levels and has a valid and reliable Turkish version. Functional independence increases as the level decreases: level I, walks without restrictions; level II, walks with restrictions; level III, walks using hand-held mobility devices; level IV, self-movement is limited and can use a motorized mobility device; level V, is transported in a hand-propelled wheelchair (15).

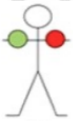
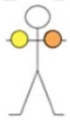
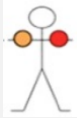
Manual Ability Classification System (MACS): It is a valid and reliable system for classifying bilateral manual ability of children with CP by Elliason et al (16). It classifies functionality in five levels and has a valid and reliable Turkish version. Functional independence increases as the level decreases: level I, can handle and use objects easily and successfully; level II, can handle and use most objects but there is a slight decrease in the speed and/or quality of accomplishment; level III, can handle and use objects with difficulty and needs help in preparing and/or changing activities; level IV, can handle and use a limited number of easily used objects in adapted situations; level V, cannot handle and use objects and has severely limited ability to perform even simple activities (17).

Communication Function Classification System (CFCS): It is a valid and reliable classification system for classifying the communication skills of children with CP by Hidecker et al (18). It classifies the communication function of children with CP in five levels. A low level indicates high functionality: level I, effective receiver and transmitter with familiar and unfamiliar partners; level II, effective but slow-flowing receiver and transmitter with familiar and/or unfamiliar partners; level III, effective transmitter and receiver with familiar partners; level IV, incompatible receiver and/or transmitter with familiar partners; level V, rarely effective transmitter and receiver even with familiar partners. The Turkish version of CFCS has high validity and reliability (19).

Bimanual Fine Motor Function Version 2.0 (BFMF-2.0): BFMF, a five-level classification system, evaluates hand function capacities (grasp, hold, and in-hand manipulation) for both hands separately in children with CP.

At Level I; one can grasp objects without restriction in both hands or with minimal restriction in more advanced fine motor activities in one hand. At Level V unable to grasp or manipulate in both hands only may hold objects placed in hand. Levels II, III, and IV are divided into two sub-levels as “a” and “b” (20). Functional asymmetric involvement of their hands was evaluated according to the BFMF-2.0. In this study, children at levels IIa, IIIa, IIIb and IVb according to BFMF-2.0 were included retrospectively (Table 1).

Table 1. Functional asymmetric hand involvement levels and definitions according to BFMF- 2.0

Level IIa		One hand: manipulates without restrictions. The other hand: only ability to grasp or hold
Level IIIa		One hand: manipulates without restrictions. The other hand no functional ability
Level IIIb		One hand: limitations in more advanced fine motor skills. The other hand: only ability to grasp or worse
Level IVb		One hand: only ability to grasp. The other hand: only ability to hold or worse

The overall ICC of BFMF-2.0 was 0.86. Cohen's weighted kappa indicated high intra-rater (κw:>0.90) and inter-rater (κw:>0.85) reliability. A high correlation was found with the

MACS (Spearman's rho = 0.89, CI: 0.86-0.91, p<0.001) (20). The Turkish version of BFMF 2.0 has high validity and reliability scores (21).

Outcome Measurements

ABILHAND-Kids: It is a parent-reported outcome measure for assessing children with neurodevelopmental problems. Parents are asked their views about the child's use of both upper limbs together during 21 activities of daily living. Each item is scored with a three-level (impossible, difficult, easy) system. Inter-rater and test-retest reliability values are above 0.90 (22). The Turkish version has been shown to be valid and reliable in children with CP (23). *Functional Independence Measure for Children (WeeFIM):* WeeFIM is a valid and reliable parent-reported outcome measure developed to assess the independence of children in daily living functions. IWeeFIM includes a total of 18 items in 6 domains: self-care, sphincter control, transfers, locomotion, communication, social and cognitive. It has three sub-dimensions as self-care, communication, and mobility (24). Turkish validity and reliability were also found to be high (25).

Statistical Analysis

IBM SPSS for Windows Version 26.0 package programe was used for statistical analyses. Skewness, Kurtosis, histogram, Detrended Plot analysis, and Kolmogorov-Smirnov tests were used to evaluate whether the distribution of the data to be used for statistical analysis was suitable for normal distribution. Mean, standard deviation and minimum-maximum values were indicated for numerical variables. Analyses of non-numerical variables were expressed as numbers and percentages.

According to BFMF 2.0 levels, children were divided into four groups as level IIa, level IIIa, level IIIb and level IVb. The chi-square test was used to compare the demographic data of the groups. Since the data were not normally distributed, the difference between the groups was analyzed by the Kruskall-Wallis test. Statistical significance was accepted as p<0.05. For pairwise comparisons, p<0.008 value was taken into consideration since there were four groups in the study.

The G*Power 3.1 program was used for the power analysis of the study. In the posthoc power analysis, WeeFIM total scores of level IV and Level IIa were used, the effect size was accepted as 2.09 and the type 1 error value was accepted as 0.05, and a sample size of 91 individuals was calculated to correspond to a power greater than 95%.

RESULTS

Data of 91 children with CP were screened for the study. According to BFMF-2.0, 62 children with functional asymmetric involvement of hands were accessed. Thirteen of them were excluded because of missing data. In this study, 49 children with CP, aged between 3 and 12 years with a mean age of 7 years were included. 26 of them were girls and 25 of them had unilateral CP. According to GMFCS levels, 80% of them could walk with or without support. According to MACS levels, 36% of them could perform bimanual activities independently. Most of the children had an understandable level of communication (Table 2).

Table 2. Demographic information of children

n=48	**M±SD**
Age, year	7.18 ± 4.52 (3-12)
	n(%)
Gender, female/male	22(53.1) / 26(46.9)
Extremity involvement	
Unilateral	27(55.1)
Bilateral	22(44.9)
GMFCS	
Level I	13(26.5)
Level II	14(28.6)
Level III	12(24.5)
Level IV	10(20.4)
MACS	
Level I	8(16.3)
Level II	10(20.4)
Level III	24(49)
Level IV	7(14.3)
CFCS	
Level I	26(53.2)
Level II	10(20.4)
Level III	13(26.4)

M, mean; SD, Standard Deviation; GMFCS, Gross Motor Function Classification Scale; MACS, Manual Ability Classification Scale; CFCS, Communication Function Classification Scale; BFMF-2.0; Bimanuel Fine Motor Function Version 2.0

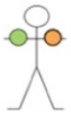
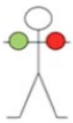
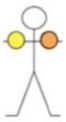
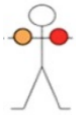
According to the BFMF 2.0 classification system, when functional asymmetric involvement of hands were classified as level IIa (n=16), level IIIa (n=12), level IIIb (n=11), and level IVb (n=10), the four groups were similar in terms of age and gender distribution (p>0.05, Table 3). Upper extremity activity performance (ABILHAND- Kids) and functional independence (WEEFIM) scores were statistically different in four groups (Table 4). Children at highly-functional BFMF 2.0 levels had higher upper extremity performance and functionality than lower ones (p<0.05).

Table 3. Comparison of groups in terms of age and gender

BFMF-2.0 levels	Level IIa n=16	Level IIIa n=12	Level IIIb n=11	Level IVb n=10	p*
Age	5.87 ± 3.86	6.25 ± 4.30	6.45 ± 5.53	5.66 ± 3.60	0.605
Gender (female/male)	7/9	7/5	6/5	6/4	0.827

*;Chi-square test, BFMF-2.0; Bimanuel Fine Motor Function Version 2.0

Table 4. Comparisons of upper extremity performance and functional independence of children with different type of asymmetric hand involvements

						pair-wise comparison
BFMF 2.0 version	**Level IIa n=16**	**Level IIIa n=12**	**Level IIIb n=11**	**Level IVb n=10**	**p**	**p***
ABILHAND-Kids	30.43 ± 6.9 (18 - 44)	15.91 ± 4.52 (10 - 27)	12.18 ± 6.75 (2 - 25)	7.88 ± 7.07 (2 - 22)	<0.001	IVb-IIIa, IVb-IIa, IIIb-IIa
WeeFIM_s	32.93 ± 9.32 (14 - 56)	30.33 ± 5.63 (18 - 38)	19.63 ± 7.20 (8 - 28)	12 ± 7.93 (8 - 26)	<0.001	IVb-IIIa, IVb-IIa
WeeFIM_m	23.68 ± 8.82 (14 - 35)	27.33 ± 5.63 (13 - 31)	16.90 ± 10.32 (5 - 30)	11 ± 10.85 (5 - 30)	0.003	IVb-IIIa, IVb-IIa
WeeFIM_c	28.43 ± 3.52 (23 - 35)	27.41 ± 7.51 (10 - 35)	21.18 ± 9.94 (5 - 30)	14.33 ± 10.08 (5 - 28)	0.007	IVb-IIIa, IVb-IIa
WeeFIM_total	85.08 ± 16.63 (51 - 126)	85.06 ± 14.94 (41 - 104)	57.72 ± 25.25 (18 - 88)	37.33 ± 27.54 (18 - 84)	<0.001	IVb-IIIa, IVb-IIa

Kruskall Wallis Test, df=3, *; p<0.008, green; without restriction, yellow; restriction in advanced fine motor skills, orange; can grasp and hold, no in-hand mobilization, red; may hold, BFMF; Bimanuel Fine Motor Function, WeeFIM; Functional Independence Measure for children, WeeFIM-s; selfcare, WeeFIM-m;mobility, WeeFIM-c; communication

DISCUSSION

In this study comparing different types of functional asymmetric hand involvements in children with CP, it was found that limitations in hand skills such as in-hand manipulation, grasp and hold affected upper extremity performance and functional independence differently. Especially in-hand manipulation had a key role in upper extremity performance and functional independence in daily living activities. Compared with functional asymmetric hand involvements, in-hand manipulation of only one hand indicated higher functional independence in self-care, mobility, and communication.

Self-care, mobility, and communication are fundamental skills to all aspects of daily living activities (4). Upper extremities produce voluntary, coordinated, and selective movements in symmetrical or asymmetrical positions bilaterally during daily living activities, e.g. using the fork and knife together while eating, reaching for two different objects independently with both hands (5,26). In typically developing children, activation of one arm or hand during a moderate function may elicit movement in the other arm or hand. As a result of brain lesions in children with CP, tonus changes, involuntary movements (mirror movements, associative reactions, etc.), inter-limb coordination

difficulties and motor control impairments limits upper extremity performance and functional independence in bimanual tasks such as self-care and mobility (2,26,27).

Previous studies have shown that gross motor function and intellectual capacity are predictive self-care activities in children with CP (28). In addition, hand use was found to be highly correlated with functional independence in selfcare activities (29). In another study, the authors reported that self-care development varied between manual ability levels in children with CP (30). In addition, children with high manual ability were more functionally independent in daily living activities (30,31). Functional asymmetry is common in children with unilateral CP and they have difficulty using the affected hand during bimanual activities. On the other hand, children with bilateral CP may also have functional asymmetric hand involvements (26). In studies comparing the self-care scores of children with CP according to extremity involvement, it was shown that upper extremity performances were not different in children with unilateral and bilateral ambulatory CP or children with bilateral CP had better performance (32). In a previous study, though children with unilateral or bilateral CP who were classified at manual ability classification level I-III exhibited similar self-care capabilities, the limited hand use was shown to contribute differently between the two groups (33). In addition, it was emphasized that children with unilateral or bilateral CP required tailored interventions according to their specific upper extremity needs in daily living activities (33). In our study, it was found that especially in-hand manipulation skill may be an important factor for self-care, mobility, communication, and upper extremity performance in children with CP whether they were unilateral or bilateral CP. In addition, children with CP were found to be more independent in functional skills if they had in-hand manipulation skills in one hand, even if they had grasping or holding skills. In-hand manipulation skill of one hand is more effective for functional independence than grasp or hold skills. Although gross motor function levels, manual ability levels and communication levels are diverse in this current study, in-hand manipulation skills were able to differentiate upper extremity performance and functionality.

In-hand manipulation is a manual ability to move an object in the palm of the hand (translation, sliding, complex rotation and simple rotation). Daily living activities such as dressing, eating, painting, brushing, bathing, and combing require in-hand manipulation skills (3,34). In children with unilateral or bilateral CP, in-hand manipulation skills in one hand may facilitate the performance of daily living activities with other hand support. If the therapeutic intervention's goal is to increase functional independence in daily living activities, it may be useful to focus more on the development of in-hand manipulation skills in children with CP.

This study had several limitations. The first was the prediction of children's functional independence in daily living activities based on parent-reported outcome measures. Second, muscle tone, selective motor control, sensory impairment in the upper extremities, and additional problems were missing. Typically developing children can reach the ability to perform self-care and social competence skills at the age of six (35). However, these skills are generally expected to be acquired later in children with CP (36). In this study, the wide age range made it impossible to predict developmental differences with an adequate sample size according to age.

CONCLUSION

In-hand manipulation skills are critical for functional independence and upper extremity performance in daily living activities of children with functional asymmetric involvement of hands. In-hand manipulation of one hand may increase the level of functional independence of the child regardless of the other hand's functional involvement in children with CP. In the future, investigating the effect of functional asymmetric upper extremity involvement on functional independence in children with CP with objective evaluation methods will be useful for guiding therapeutic interventions.

Researcher Contribution: KSB: Study idea, data analysis, literature review, article writing; MKG: determination of appropriate patient files, consultancy about study management

Acknowledgments: We would like to thank all the researchers, children, and their parents at the Cerebral Palsy and Rehabilitation Unit for their support.

Conflict of Interest Statement: There is no conflict of interest to be declared.

How to cite this article: Seyhan-Bıyık K, Kerem-Günel M, Different Types of Asymmetric Hand Involvements and Functional Independence in Children with Cerebral Palsy: A Retrospective Study. Journal of Hacettepe University Physical Therapy and Rehabilitation. 2024;2(3),87-94.

REFERENCES

1. Bonden H, Jahnsen RB, Klevberg GL. Self-care and hand function in preschool children with unilateral or bilateral cerebral palsy: A cross-sectional study. Child Care Health Dev. 2024;50(1):e13208.
2. Arner M, Eliasson A-C, Nicklasson S, Sommerstein K, Hägglund, G. Hand function in cerebral palsy. Report of 367 children in a population-based longitudinal health care program. J Hand Surg. 2008;33(8):1337-47.
3. Elvrum AKG, Sæther R, Riphagen II,Vik T. Outcome measures evaluating hand function in children with bilateral cerebral palsy: a systematic review. Dev Med Child Neurol. 2016;58(7):662-71.
4. Burgess A, Boyd RN, Chatfield MD, Ziviani J, Wotherspoon J,et al. Hand function and self-care in children with cerebral palsy. Dev Med Child Neurol. 2021;63(5):576-83.
5. Hung Y-C, Zeng W. Accuracy constraints improve symmetric bimanual coordination for children with and without unilateral cerebral palsy. Dev Neurorehabil. 2020;23(3):176-84.
6. Hung Y-C, Robert MT, Friel KM, Gordon AM. Relationship between integrity of the corpus callosum and bimanual coordination in children with unilateral spastic cerebral palsy. Front Hum Neurosci. 2019;13:334.
7. Seyhan-Bıyık K, Delioğlu K, Tunçdemir M, Üneş S, Özal C, Kerem-Günel M. Asymmetric involvement of hands: Psychometric properties of the Turkish version of the Bimanual Fine Motor Function 2.0 classification in children with cerebral palsy. J Hand Ther. 2024;37(3):429-437.
8. Uswatte G, Taub E, Griffin A, Vogtle L, Rowe J, Barman J. The pediatric motor activity log-revised: assessing real-world arm use in children with cerebral palsy. Rehabil Psychol. 2012;57(2):149-158.
9. Mailleux L, Decraene L, Kalkantzi A, et al. Spatiotemporal coordination in children with unilateral cerebral palsy: Insights from a bimanual goal-directed task. Eur J Paediatr Neurol. 2024;53:73-87.
10. Gerber CN, Labruyère R, van Hedel HJ. Reliability and Responsiveness of Upper Limb Motor Assessments for Children With Central Neuromotor Disorders: A Systematic Review. Neurorehabil Neural Repair. 2016;30(1):19-39. doi:10.1177/1545968315583723
11. Wagner LV, Davids JR. Assessment tools and classification systems used for the upper extremity in children with cerebral palsy. Clin Orthop Relat Res. 2012;470(5):1257-1271.
12. Dong VA, Tung IH, Siu HW, Fong KN. Studies comparing the efficacy of constraint-induced movement therapy and bimanual training in children with unilateral cerebral palsy: a systematic review. Dev Neurorehabil. 2013;16(2):133-143.
13. Klepper SE, Clayton Krasinski D, Gilb MC, Khalil N. Comparing Unimanual and Bimanual Training in Upper Extremity Function in Children With Unilateral Cerebral Palsy. Pediatr Phys Ther. 2017;29(4):288-306.
14. Palisano R, Rosenbaum P, Walter S, Russell D, Wood E, Galuppi B. Development and reliability of a system to classify gross motor function in children with cerebral palsy. Dev Med Child Neurol. 1997;39(4):214-223.
15. Eliasson AC, Krumlinde-Sundholm L, Rösblad B, Beckung E, Arner M, Ohrvall AM, et al. The Manual Ability Classification System (MACS) for children with cerebral palsy: scale development and evidence of validity and reliability. Dev Med Child Neurol. 2006;48(7):549-554.
16. El O, Baydar M, Berk H, Peker O, Koşay C, Demiral Y. Interobserver reliability of the Turkish version of the expanded and revised gross motor function classification system. Disabil Rehabil. 2012;34(12):1030-3.
17. Akpinar P, Tezel CG, Eliasson AC, Icagasioglu A. Reliability and cross-cultural validation of the Turkish version of Manual Ability Classification System (MACS) for children with cerebral palsy. Disabil Rehabil. 2010;32(23):1910-6.
18. Hidecker MJ, Paneth N, Rosenbaum PL, Kent RD, Lillie J, Eulenberg JB, et al. Developing and validating the Communication Function Classification System for individuals with cerebral palsy. Dev Med Child Neurol. 2011;53(8):704-710.
19. Mutlu A, Kara ÖK, Livanelioğlu A, Karahan S, Alkan H, Yardımcı BN, et al. Agreement between parents and clinicians on the communication function levels and relationship of classification systems of children with cerebral palsy. Disabil Health J. 2018;11(2):281-6.
20. Elvrum AK, Andersen GL, Himmelmann K, Beckung E, Öhrvall AM, Lydersen S, et al. Bimanual Fine Motor Function (BFMF) Classification in Children with Cerebral Palsy: Aspects of Construct and Content Validity. Phys Occup Ther Pediatr. 2016;36(1):1-16.
21. Seyhan-Bıyık K, Delioğlu K, Tunçdemir M, Üneş S, Özal C, Kerem-Günel M. Asymmetric involvement of hands: Psychometric properties of the Turkish version of the Bimanual Fine Motor Function 2.0 classification in children with cerebral palsy. J Hand Ther. 2024;37(3):429-437.
22. Arnould C, Penta M, Renders A, Thonnard JL. ABILHAND-Kids: a measure of manual ability in children with cerebral palsy. Neurology. 2004;63(6):1045-1052.
23. Şahin E, Dilek B, Karakaş A, Engin O, Gülbahar S, Faruk Dadaş Ö, et al.Reliability and validity of the Turkish version of the ABILHAND-kids survey in children with cerebral palsy. Turk J Phys Med Rehabil. 2020;66(4):444.
24. Liu M, Toikawa H, Seki M, Domen K, Chino N. Functional Independence Measure for Children (WeeFIM): a preliminary study in nondisabled Japanese children. Am J Phys Med Rehabil. 1998;77(1):36-44.
25. Tur BS, Küçükdeveci AA, Kutlay S, Yavuzer G, Elhan AH, Tennant A. Psychometric properties of the WeeFIM in children with cerebral palsy in Turkey. Dev Med Child Neurol. 2009;51(9):732-8.
26. Dellatolas G, Filho GN, Souza L, Nunes LG, Braga LW.Manual skill, hand skill asymmetry, and neuropsychological test performance in schoolchildren with spastic cerebral palsy. Laterality. 2005;10(2):161-82.
27. Bueno SA, Mancini MC, Oliveira RHS, Airoldi MJ, Vieira BS, Gordon AM, et al. Bimanual hand use in children and adolescents with unilateral spastic cerebral palsy: an exploratory study. Braz J Phys Ther. 2023;27(6):100561.
28. Kerem-Günel M, Arslan UE, Seyhan-Bıyık K, Özal C, Numanoğlu-Akbaş A, Üneş S, et al. Evaluation of daily and social participation of children with Cerebral Palsy across different age groups with a focus on the 'F'-words: Function, family, fitness, fun, friends and future. Res Dev Disabil. 2023;140:104588.

29. Öhrvall AM, Eliasson AC, Löwing K, Ödman P, Krumlinde-Sundholm L.Self-care and mobility skills in children with cerebral palsy, related to their manual ability and gross motor function classifications. Dev Med Child Neurol. 2010;52(11):1048-55.

30. Gunel MK, Mutlu A, Tarsuslu T, Livanelioğlu A. Relationship among the Manual Ability Classification System (MACS), the Gross Motor Function Classification System (GMFCS), and the functional status (WeeFIM) in children with spastic cerebral palsy. Eur J Pediatr. 2009;168:477-85.

31. Smits DW, Ketelaar M, Gorter JW, van Schie P, Dallmeijer A, Jongmans M, et al.Development of daily activities in school-age children with cerebral palsy. Res Dev Disabil. 2011;32(1):222-34.

32. Park H, Choi JY, Yi SH, Park ES, Shim D, Choi TY, et al. Relationship between the more-affected upper limb function and daily activity performance in children with cerebral palsy: a cross-sectional study. BMC Pediatr. 2021;21:1-8.

33. Klevberg GL, Østensjø S, Krumlinde-Sundholm L, Elkjær S, Jahnsen RB. Hand function in a population-based sample of young children with unilateral or bilateral cerebral palsy. Phys Occup Ther Pediatr. 2017;37(5):528-40.

34. Elvrum AG, Zethræus BM, Vik T, Krumlinde-Sundholm L.Development and validation of the both hands assessment for children with bilateral cerebral palsy. Phys Occup Ther Pediatr. 2018;38(2):113-26.

35. Alkan IB, Cavusoglu H. Examining the effectiveness of education based on social learning theory in fostering self-care and social skills in school children: A randomized controlled trial. J Pediatr Nurs.2024;78:e448-e59.

36. Palisano RJ, Chiarello LA, Avery L, Hanna S; On Track Study Team. Self-care trajectories and reference percentiles for children with cerebral palsy. Phys Occup Ther Pediatr. 2020;40(1):62-78.