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Efficacy of Dual Task Training versus Conventional Therapy on Hand Function and Visual Perception Ability in Children with Cerebral Palsy

Nekar Daekook M, Jae Ho Yu*, Hye Yun Kang, Dong Yeop Lee, Ji Heon Hong, Seong Gil Kim

Department of Physical Therapy, Sunmoon University, South Korea

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Abstract This pilot study aimed to assess the effect of dual-task training, compared to conventional therapy on the hand functional ability and visual perception in children with cerebral palsy. It was a pretest-posttest control group design, conducted for 4 weeks with ten children ranged between 5-13 years old. Participants were randomly allocated either to the experimental group (dual-task training) or the control group (conventional treatment). The experimental group received the usual physical therapy session and dual-task training sessions 3 sessions/week for 4 weeks. The control group received only the conventional physical therapy 3 sessions/week for 4 weeks. Fine and gross motor hand function were assessed by the Jebsen-Taylor hand function test and the Motor-free Visual Perception Test 3rd edition was used to assess visual perceptual ability before intervention and at 4 weeks after intervention. Only the experimental group showed an improvement in hand function ($p<0.05$) and no significant differences were observed between the groups ($p>0.05$). Statistically significant changes were noticed in three of the five subscales of the visual perception in the experimental group ($p<0.05$) with the experimental group superior to the control group. These findings suggest that dual-task training conducted with a precise goal to achieve (problem-solving) and including cognitive tasks is beneficial in means of improving hand function and visual perceptional ability of children with hemiplegic cerebral palsy with a short-term effect. However, further studies on children with cerebral palsy with a similar approach are warranted.

Keywords Cerebral Palsy, Dual-Task Training, Hand Function, Visual Ability

1. Introduction

Cerebral palsy (CP) is widely known as the most common cause of the neuropediatric disorder and physical impairment affecting children. It is an umbrella term describing a group of non-progressive impairments which occurs in the very early days of child development [1,2]. It results from prenatal, perinatal, or postnatal static brain lesions or abnormal brain development followed by a group of neurodevelopmental disorders [2]. Cerebral palsy has been classified variously according to movement abnormality/degree of muscle tone (spastic, ataxic, dyskinetic, mixed), by the most affected region (monoplegia, hemiplegia, diplegia, triplegia, quadriplegia) or by the gross motor ability using the Gross Motor Function Classification System (GMFCS) [3,4,5]. Despite the fact that children may have varied symptoms according to the type of cerebral palsy. Common conditions are movement disorder, abnormal posture, sensory, cognition, coordination, mental disorder, epilepsy, and musculoskeletal impairment [6,7].

Among children with cerebral palsy, around 25% have spastic hemiplegia [8]. Besides, children with hemiplegic cerebral palsy have been reported to have a high level of cognition, capable of self-ambulation, and less affected functional abilities [8,9,10]. However, hemiplegic cerebral palsy usually affects more gravely the upper extremity than the trunk and lower extremity [11]. Children may have an abnormal hand posture with excessive thumb adduction and flexion and restricted active wrist extension [11,12]. This results in difficulty in using hand functions in daily activities such as reaching, holding, and grasping.

Generally, abnormal brain development may involve a decrease in visual perspicacity and visual field, oculomotor dysfunction, and complex associative disorders usually referred visual perception ability impairment [13]. Perceptional and cognitive disorder, the visual perceptional ability is an essential element for a successful self-care task performance and participation in society-related activities.

Visual perception ability is reported to have a significant correlation with the dominant upper limb ability in children with cerebral palsy [14]. The same correlation was found in older adults as impaired visual perception ability may influence hand function in general and manual dexterity in particular [15]. Moreover, a poor upper limb-hand function may lead to a decrease in visuospatial and visuo-temporal ability resulting in difficulties in activities of daily life. Besides, most daily activities require simultaneous execution of 2 or more functional tasks. Though, dual-task training which is the performance of more than one task different from nature at the same time has been proved to be effective for postural control (involving attention, eye movement, muscle recruitment, etc.) in children with hemiplegic cerebral palsy [16]. Furthermore, it has been reported effective for hand function in children with hemiplegic cerebral palsy [17]. However, there is no study that investigated the effect of cognitive-motor dual training on hand function and visual perception ability in children with hemiplegic cerebral palsy. Therefore, the aim of the present study was to examine the effects of dual-task training compared to conventional therapy on hand and visual function in children with cerebral palsy. We hypothesized that dual-task training would enhance hand function and visual perception ability and be superior to conventional therapy for children with cerebral palsy.

2. Materials and Method

2.1. Study Design

This study was a pre-test-post-test control group design, single-center conducted in a pediatric center located in Seoul, Korea and approved by the Institutional Review Board of Sunmoon University. Prior to participation, all children's parents/legal guardians received explanations regarding the details of the study, and conscious consent was obtained.

2.2. Participants

Ten (10) children ranging from 5 to 14 years old, 7 boys and 3 girls were recruited for this study. Participants were included after receiving written consent from parents/legal guardians who voluntarily accepted their children to participate in the study. The inclusion criteria were children diagnosed with hemiplegic cerebral palsy, those with upper extremity muscle tone scores less than three (3) on the modified Ashworth scale, those able to hear, understand, and follow basic tasks, those who did not receive injections of anti-spastic to reduce rigidity within the last 2 months. Those who did not satisfy the above-required selection criteria were excluded. Participants were equally and randomly allocated to either the experiment group (n=5) or the control group (n=5).

The randomization was performed by an independent hospital personnel (receptionist) using Microsoft Excel who assigned participants to their respective groups without knowing the nature of the intervention (experiment or control).

Table 1. General characteristics of participants

	Experimental group (n=5)	**Control group (n=5)**
Gender	4boys, 1girls	3boys, 2girls
Age	10.3±3.9	10.8±3.6
Height(cm)	128.8±18.4	129.5±21.2
Weight(kg)	29.4±12.7	31.1±12.4
Diagnoses	3left hemiplegia, 2right hemiplegia	4left hemiplegia, 1right hemiplegia
MAS	1.90±.87	2.00±.66

mean±standard deviation, MAS: Modified Ashworth Scale

2.3. Measurements

In this study, the measurement was conducted twice, one before and one after the intervention program. All the measurements were performed by a therapist blinded to the participants' group allocations. We used the Jebsen-Taylor Hand Function (JTHF) to assess hand function and the Motor-free Visual Perception Test 3rd edition (MVPT-3).

The Jebsen-Taylor Hand Function Test is one of the standardized hand function tests which is a task performance-based measurement with good to excellent test-retest reliability [18,19]. It consists of seven (7) subtests (1) Writing; (2) Simulated page turning, (3) Lifting small, common objects; (4) Simulated feeding; (5) Stacking checker; (6) Lifting large, light object; (7) Lifting large, heavy object, evaluating overall the function of the upper limbs, especially the fine and gross motor ability. However, in the present study, only 6 subtests were assessed excluding the "writing" subtest since some children unable to write were included in the experiment.

The Motor-free Visual Perception Test 3rd edition is a measurement tool designed to evaluate visual perceptual ability regardless of any motor skill involvement which is totally adapted to the present study's participants. It is a reliable and valid screening tool [20]. The MVPT-3 is used specifically to assess (1) spatial relationship, (2) visual discrimination, (3) figure-ground (4) visual closure, and (5) visual memory.

2.4. Intervention

2.4.1. Experimental group

The children allocated to the experimental group received a goal-centered dual-task training program added to the basic hand function training program given to the control group. The training session lasted 30min/session, plus 15 min for the dual-task training all for 4 weeks. The tasks were goal-centered problem solving designed in a simple way to be easily followed by the participants and included activities involving functional hand movement while performing simultaneously a cognitive task associated with visual perceptional ability. The training consisted primarily of passive stretching of wrist and elbow flexor and forearm pronator muscles, neurodevelopmental training using proximal and distal key points of control for the upper extremity, and protective extensor thrust to improve protective reactions. Secondary, griping, reaching, holding, and object manipulation exercises were performed with a goal to achieve while training for visual perception ability. At the therapist's verbal and gesture command, participants were instructed to pick objects from a toy bag and to range them according to their colors, shapes (triangles, rectangle, circular), and size (small, medium, big) and naming each object with their color and shape. Prior to the execution of the task, the therapist in charge demonstrated the task and explained the procedure to facilitate understanding.

2.4.2. Control group

All the children allocated to the control group received a 30min session of usual physical therapy conducted by the therapist in charge. The hand training session consisted of a neurodevelopmental treatment program using proximal and distal key points of control for the upper limbs, gentle and gradually prolonged passive stretching of the muscle liable to be tight (wrist flexors, elbow flexor, forearm pronator), wrist and elbow extensor strengthening, upper limbs weight-bearing exercise, protective extensor thrust to improve protective reactions, basic handgrip with various objects with different size, shape, and weight (ball, cup, toy, bowl, spoon, etc.), reaching and holding exercises. They all received additional electrical stimulation on the wrist extensor muscles to stimulate wrist extension. The program was conducted 3times a week for 4 weeks. Figure 1 below displays the flow diagram outlining the study procedure.

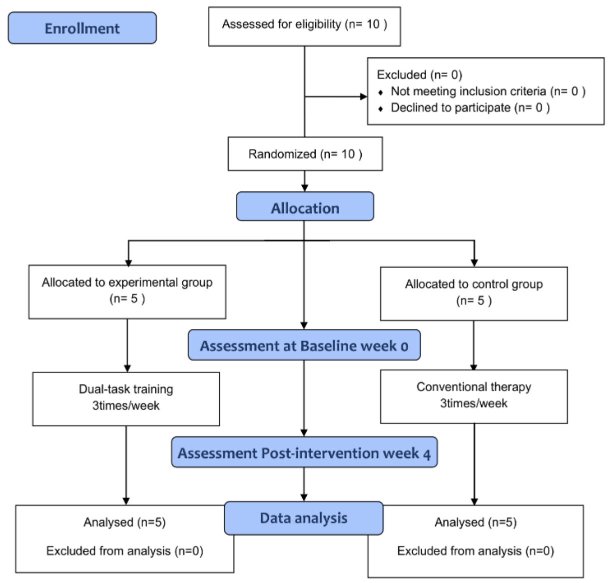

Figure 1. Study procedure

3. Data Analysis

Data were analyzed using IBM SPSS Statistics Version 26.0. Armonk, NY for windows. Descriptive statistical analysis was conducted for the general characteristics of the participants and expressed as mean standard deviation. Because the participant's most affected side (hemiplegic side, diplegic) was not distributed normally and the sample size was very small, a nonparametric Wilcoxon signed-rank test was used to define changes within the groups, and a Mann–Whitney U-test was chosen to compare the difference of values between the groups. $P<0.05$ was set to indicate statistical significance.

4. Results

The mean age of the experiment group was 10.3±3.9 years, 80% were boys and 20% were girls with 60% left hemiplegic, and 40% right hemiplegic. In the control group, the mean age was 10.8±3.6 years, 60% were boys and 40% were girls with 80% left hemiplegic and 20% right hemiplegic. The comparison of pre-intervention and post-intervention of hand function within each group and between group differences are shown in Table 2. We observed a significant difference in almost all JTHF variables ($p<0.05$) in the experimental group (both right and left side) expecting staking checker (p>0.05). Regarding the changes in hand function in the control groups, we observed a significant difference between the pre-intervention and post-intervention in almost all JTHF variables (0<0.05) expecting staking checker and lifting large heavy object (p>0.05). Moreover, the between groups comparison did show a significant difference in Lifting large heavy object (right and left) and lifting large light object (right) (p<0.05). All the other variables on both the right and left sides did not show a significant difference (p>0.05). The comparison of the within group pre-post intervention and the between group comparison of visual perception ability is shown below in Table 3. The result showed a significant difference between the pre-intervention and post-intervention in the experimental group in the spatial relationship, visual discrimination, and figure-ground (p<0.05). In the control group, a significant difference was observed only in the spatial relationship (p<0.05). Moreover, during the comparison of the two (2) groups, there was not a significant difference in almost all variables expecting spatial relationship and visual discrimination which were superior in the experimental group to the control group (p<0.05).

Table 2. Changes in hand function ability within group and between group

		Experimental group			**Control group**			
Variables	Side	Pre-test	Post-test	*t*	Pre-test	Post-test	*t*	*p*
Simulated page turning	Rt	10.50±8.83	14.48±7.58	-2.023*	9.20±2.89	13.39±5.80	-2.023*	.841
	Lt	13.46±14.19	18.87±13.63	-2.023*	13.46±14.19	15.02±13.40	-2.023*	.151
Lifting small objects	Rt	12.93±7.25	21.30±10.88	-2.023*	14.26±7.04	21.46±7.14	-2.023*	1.000
	Lt	20.99±18.55	34.21±25.27	-2.023*	20.99±18.55	26.44±17.03	-2.023*	.548
Simulated feeding	Rt	19.71±5.68	24.35±4.65	-2.023*	23.66±5.74	29.14±6.27	-2.023*	.421
	Lt	15.15±44.85	20.34±66.18	-2.023*	23.35±7.81	29.78±6.70	-2.023*	.151
Stacking checker	Rt	11.18±9.33	10.32±8.7	-.674	8.84±4.59	6.71±3.40	-1.753	1.000
	Lt	11.73±10.31	12.17±21.43	-1.214	11.85±11.22	12.31±10.88	-.944	.841
Lifting large light object	Rt	8.95±7.04	14.50±8.39	-2.023*	9.91±6.45	5.85±1.48	-2.023*	.008*
	Lt	11.55±12.07	22.44±26.82	-2.023*	13.55±7.72	18.25±8.53	-2.023*	.690
Lifting large heavy object	Rt	9.17±8.70	13.45±8.06	-2.023*	8.05±3.86	7.54±3.89	-1.483	.008*
	Lt	13.20±17.99	32.32±23.67	-2.023*	9.20±9.08	9.79±8.82	-1.483	.008*

mean±standard deviation, Rt: right, Lt: left, t: Wilcoxon signed-rank test, p: Mann–Whitney U-test, *p<0.05

Table 3. Changes in visual perception ability within group and between group

	Experimental group			**Control group**			
Variables	Pre-test	Post-test	*t*	Pre-test	Post-test	*t*	*p*
Spatial relationship	2.40±1.67	6.00±1.41	-2.032*	3.60±1.51	7.40±1.51	-2.060*	.841*
Visual discrimination	5.60±2.88	10.60±2.88	-2.041*	5.60±2.07	6.00±1.87	-1.000	.016*
Figure-ground	3.40±1.51	8.00±1.00	-2.060*	3.20±1.48	3.80±1.64	-1.342	.008
Visual closure	6.00±3.39	6.40±4.33	-.5552	6.40±2.96	6.80±3.42	-.816	1.000
Visual memory	5.40±2.19	5.40±2.70	.000	6.40±1.67	6.60±1.51	.577	1.000

mean±standard deviation, t: Wilcoxon signed-rank test, p: Mann–Whitney U-test, *p<0.05

5. Discussion

The current pilot study aimed to evaluate the effect of goal-oriented dual-task training and compared it to conventional physical therapy training on hand function and visual perception ability of children with hemiplegic cerebral palsy. The main findings of this study are that dual-task training and conventional training were both beneficial for hand function rehabilitation, but only dual-task training influenced visual perception ability.

Children having hemiplegic cerebral palsy usually have muscle weakness in the wrist extensor muscles and high muscle tone in flexors [21]. Apart from muscle weakness and spasticity, children struggle with active movement of hand reported to be caused by a lack of motor unit recruitment. [16,22]. However, studies have proved that restricted use of the less affected hand (uninvolved side) to the detriment of the most affected side (involved hand) referred as constraint-induced movement therapy (CIMT) facilitates motor unit recruitment and improves hand function in hemiplegic cerebral palsy [23,24,25].

In the present study, our result was similar between the experimental group and the control group for the hand function except for lifting a large heavy object (right and left side) and lifting a large and light object (right side). This improvement of hand function in children of both groups without a major difference between them can be explained by the similarity of basic hand function training they received. Passive gradually maintain stretching of wrist flexors, elbow flexors, and forearm pronation accompanied with extensors strengthening are the basic training related to hand muscle condition [26]. Additionally, restricted use of less affected hand and intensive use of affected hand during the training in both groups may explain the present results. A similar explanation was found in a previous study declaring the forced use of the affected hand enhances the improvement of hand function [11].

The improvement of visual perception ability in the experiment group may be attributed to the consistency of the added cognitive task, which was consisted of the organization by color, shape, and size of the different objects while naming each object according to its color and shape. This did not have a beneficial effect on visual closure and visual memory but affected visual spatial skills (e.g., depth, distance), visual discrimination skills (e.g., discerning differences between object shape, color, size), figure-ground skills (understanding what they see, e.g., differentiate picture from its background). The explanation of why visual closure which is the ability to recognize an object/picture and visual memory which is the ability to register a piece of visual information did not improve may be due to decreased intellectual ability of participants of this study. Previous studies have shown a correlation between intellectual capacity and visual memory which supports the result of our study [27,28]. Moreover, repetitive practice of a certain exercise or movement may enhance brain reorganization which may also be considered as a part of motor learning.

In a previous study on hemiplegic patients, authors reported that repetitive training may have limited effect if performed without any goal to achieve or problem to solve [29]. We also notice that children with cerebral palsy as the majority of children with developmental disorders need constant stimulation and motivation helping in physical and social participation. In other words, goal-oriented, problem-solving repetitive training conducted simultaneously with cognitive training as performed in the present study facilitates movement execution and improvement of hand function as well as some ability of visual perception.

However, this study has several limitations. First, the sample size was very small, the gender repartition was not equal and the distribution of the side of the hemiplegia was not equal. Thus, it reduces the possibility to generalize the result to a large sample size. Secondly, the intervention was conducted just 3 times a week for 4 weeks for a total of 12 sessions without a follow-up. Future research is needed to investigate the long-term effect of dual-task training on hand function and visual perception ability in children with hemiplegic cerebral palsy. However, despite these limitations, the results of this pilot study were able to assess the differences between dual-task training and conventional physical therapy training for this population.

6. Conclusion

The main conclusion of the present study is that the dual-task training conducted with a precise goal to achieve (problem-solving) and including cognitive tasks does not have only a beneficial effect on hand functions but also on visual perception ability, especially on spatial relation, visual discrimination, and figure ground. Moreover, conventional physical therapy training for hand function has a statistically significant effect on hand function but does not influence visual perception ability in children with cerebral palsy. Besides, these findings represented a promising treatment approach for hand management in children with cerebral palsy and further studies are needed to investigate rigorously a long-term effect.

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Conflict of Interest

The authors declare no conflict of interest.

REFERENCES

[1] Picelli A, La Marchina E, Vangelista A, Chemello E, Modenese A, Gandolfi M, Ciceri EF, Bucci A, Zoccatelli G, Saltuari L, Waldner A., "Effects of Robot-Assisted Training for the Unaffected Arm in Patients with Hemiparetic Cerebral Palsy: A Proof-of-Concept Pilot Study," Behavioural Neurology, vol. 2017, 2017. DOI: 10.1155/2017/8349242.

[2] Koman LA, Smith BP, Shilt JS., "Cerebral palsy," THE LANCET, vol. 363, no. 9421, pp. 1619-1631, 2004. DOI: 10.1016/S0140-6736(04)16207-7.

[3] Surveillance of Cerebral Palsy in Europe, "Definition, eligibility criteria and classification of CP subtypes," in SCPE guide for the registration of cerebral palsy. Instructions and reference, version 2016, SCPE, 2016, pp. 4-5.

[4] Peterson N, Walton R., "Ambulant cerebral palsy," Orthopaedics and Trauma, vol. 30, no. 6, pp. 525-538, 2016. DOI: 10.1016/j.mporth.2016.08.005.

[5] Wimalasundera N, Stevenson VL., "Cerebral palsy," Practical Neurology, vol. 16, no. 3, pp. 184–194, 2016. DOI: 10.1136/practneurol-2015-001184.

[6] Aisen ML, Kerkovich D, Mast J, Mulroy S, Wren TA, Kay RM, Rethlefsen SA., "Cerebral palsy: clinical care and neurological rehabilitation," The Lancet Neurology, vol. 10, no. 9, pp. 844-852, 2011. DOI: 10.1016/S1474-4422(11)70 176-4.

[7] Hernandez - Reif M, Field T, Largie S, Diego M, Manigat N, Seoanes J, Bornstein J., "Cerebral palsy symptoms in children decreased following massage therapy," Early Child Development and Care, vol. 175, no. 5, pp. 445-456, 2005. DOI: 10.1080/0300443042000230546.

[8] Patel DR, Neelakantan M, Pandher K, Merrick J., "Cerebral palsy in children: a clinical overview," Translational pediatrics. (Suppl 1): S125-S135, 2020. DOI: 10.21037/tp.2020.01.01.

[9] Graham HK, Rosenbaum P, Paneth N, Dan B, Lin JP, Damiano DL, Becher JG, Gaebler-Spira D, Colver A, Reddihough DS, Crompton KE, Lieber RL., "Cerebral palsy," Nature Reviews Disease Primers, vol. 2, no. 15082, 2016. DOI: 10.1038/nrdp.2015.82.

[10] Oskoui M, Shevell MI, Swaiman KF., "Cerebral palsy," In: Swaiman's Pediatric Neurology: principles and practice. 6th ed, Philadelphia: Elsevier, 2017, e1660-72.

[11] El-Shamy SM, El-Banna MF., "Effect of Wii training on hand function in children with hemiplegic cerebral palsy," Physiotherapy theory and practice, vol. 36, no. 1, pp. 38-44, 2020. DOI: 10.1080/09593985.2018.1479810.

[12] Basu AP, Pearse J, Kelly S, Wisher V, Kisler J., "Early intervention to improve hand function in hemiplegic cerebral palsy," Frontiers in neurology, vol. 6, no. 5, pp. 281, 2015. DOI: 10.3389/fneur.2014.00281.

[13] Ego A, Lidzba K, Brovedani P, Belmonti V, Gonzalez - Monge S, Boudia B, Ritz A, Cans C., "Visual–perceptual impairment in children with cerebral palsy: a systematic review," Developmental Medicine & Child Neurology, vol. 57, pp. 46-51, 2015. DOI: 10.1111/dmcn.12687.

[14] James S, Ziviani J, Ware RS, Boyd RN., "Relationships between activities of daily living, upper limb function, and visual perception in children and adolescents with unilateral cerebral palsy," Developmental Medicine & Child Neurology, vol. 57, no. 9, pp. 852-857, 2015. DOI: 10.1111/dmcn.12715.

[15] Song CS., "Relationship between visuo-perceptual function and manual dexterity in community-dwelling older adults," Journal of physical therapy science, vol. 27, no. 6, pp. 1871-1874, 2015. DOI: 10.1589/jpts.27.1871.

[16] Elhinidi EI, Ismaeel MM, El-Saeed TM., "Effect of dual-task training on postural stability in children with infantile hemiparesis," Journal of physical therapy science, vol. 28, no. 3, pp. 875-880, 2016. DOI: 10.1589/jpts.28.875.

[17] Zakaria HM, Adel SM, El Shennawy SA., "Efficacy of Dual Task Specific Training on Upper-Extremity Function of Hemiplegic Cerebral Palsy," Bulletin of Faculty of Physical Therapy, vol. 14, no. 1, 2009.

[18] Araneda R, Ebner - Karestinos D, Paradis J., Saussez G, Friel KM, Gordon AM, Bleyenheuft Y. "Reliability and responsiveness of the Jebsen - Taylor Test of Hand Function and the Box and Block Test for children with cerebral palsy," Developmental Medicine & child neurology, vol.61, no. 10, pp.1182-1188, 2019. DOI: 10.1111/dmcn.14184.

[19] Sığırtmaç İC, Öksüz Ç., "Investigation of reliability, validity, and cutoff value of the Jebsen-Taylor Hand Function Test," Journal of Hand Therapy, vol. 34, no. 3, pp. 396-403, 2021, DOI: 10.1016/j.jht.2020.01.004.

[20] McCane SJ., "Test review: motor-free visual perception test," Journal of Psychoeducational Assessment, vol. 24, no. 3, pp. 265-272, 2006. DOI: 10.1177/0734282906286339.

[21] Bhardwaj P, Sabapathy SR., "Assessment of the hand in cerebral palsy," Indian Journal of Plastic Surgery, vol. 44, no. 2, pp. 348-356, 2011. DOI: 10.4103/0970-0358.85356.

[22] Rose J, McGill KC., "Neuromuscular activation and motor-unit firing characteristics in cerebral palsy," Developmental medicine and child neurology, vol. 47, no. 5, pp.329-336, 2005. DOI: 10.1017/s0012162205000629.

[23] Xu K, Wang L, Mai J, He L., "Efficacy of constraint-induced movement therapy and electrical stimulation on hand function of children with hemiplegic cerebral palsy: a controlled clinical trial," Disability and Rehabilitation, vol. 34, no. 4, pp. 337–346, 2012. DOI: 10.3109/09638288.2011.607213.

[24] Chen YP, Pope S, Tyler D, Warren GL., "Effectiveness of constraint-induced movement therapy on upper-extremity function in children with cerebral palsy: a systematic review and meta-analysis of randomized controlled trials," Clinical Rehabilitation, vol. 28, no. 10, pp. 939-953, 2014. DOI: 10.1177/0269215514544982.

[25] Hoare BJ, Wallen MA, Thorley MN, Jackman ML, Carey LM, Imms C., "Constraint - induced movement therapy in children with unilateral cerebral palsy," Cochrane database of systematic reviews, vol. 4, no. 4, 2019. DOI: 10.1002/14651858.CD004149.pub3.

[26] Kawahira K, Shimodozono M, Etoh S, Kamada K, Noma T, Tanaka N., "Effects of intensive repetition of a new facilitation technique on motor functional recovery of the

hemiplegic upper limb and hand," Brain Injury., vol. 24, no. 10, pp. 1202-1213, 2010. DOI: 10.3109/02699052.2010.506855.

[27] Zakharov IM, Voronin IA, Ismatullina VI, Malykh SB., "The relationship between visual recognition memory and intelligence," Procedia-Social and Behavioral Sciences, vol. 233, pp. 313-317, 2016. DOI: 10.1016/j.sbspro.2016.10.142.

[28] Rakhmanov O, Dane S., "Correlations among IQ, visual memory assessed by ROCF test and GPA in university students," Journal of Research in Medical and Dental Science, vol. 8, no. 3, pp. 1-5, 2020.

[29] Feys HM, De Weerdt WJ, Selz BE, Cox Steck GA, Spichiger R, Vereeck LE, Putman KD, Van Hoydonck GA., "Effect of a therapeutic intervention for the hemiplegic upper limb in the acute phase after stroke: a single-blind, randomized, controlled multicenter trial.," Stroke, vol. 29, no. 4, pp. 785-792, 1998. DOI: 10.1161/01.STR.29.4.785.