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ORIGINAL ARTICLE

Upper limb training using visual feedback for children with cerebral palsy

Dilara Merve SARI[1], Tuğba KURU ÇOLAK[2]

Purpose: This study aimed to investigate that if upper limb visual feedback training added to the usual therapy was effective on upper limb functions in children with cerebral palsy.
Methods: Thirty-eight children with cerebral palsy (4-18 years) participated in the study. The participants were randomly assigned into two groups. Study group (n=19, mean age 8.50±3.40, 53% female) received visual feedback training plus usual therapy twice a week for 8 weeks, 16 sessions in total, while control group (n=19, mean age 10.60±3.80, 42% female) received only usual therapy. The participants' Gross Motor Function Classification System levels were between I-III and spasticity levels were between '0' to '1+' according to Modified Ashworth Scale. Upper limb range of motion (ROM), grip and pinch strength, hand skills (Minnesota Manual Dexterity Test (MMDT)), and functional abilities (Childhood Health Assessment Questionnaire (CHAQ)) were assessed before and after treatment.
Results: The change amount in shoulder flexion (p=0.004) and abduction (p=0.01), supination (p=0.019) and wrist flexion (p=0.004) and extension (p=0.00) ROM values; bilateral MMDT scores (p=0.003) were statistically significantly improved in study group compared to control group.
Conclusion: Adding visual feedback training to the usual therapy program of children with cerebral palsy was found to be effective in some outcome measurements such as upper limb ROM and hand skills. In the long-term rehabilitation process, this new training method may be an alternative additive option for children, families, and physiotherapists.
Keywords: Cerebral palsy, Upper limb, Rehabilitation, Feedback.

Serebral palsili çocuklarda görsel geri bildirim kullanımı ile üst ekstremite eğitimi

Amaç: Bu çalışmanın amacı, serebral palsi tanısı olan çocuklarda rutin tedaviye eklenen üst ekstremite görsel geribildirim eğitiminin üst ekstremite fonksiyonları üzerine etkisini araştırmaktı.
Yöntem: Çalışmaya serebral palsi tanılı (4-18 yaş) 38 çocuk katıldı. Katılımcılar randomize olarak iki gruba ayrıldı. Çalışma grubu (n=19, ortalama yaş 8,50±3,40, %53 kadın) 8 hafta boyunca haftada 2 kez görsel geribildirim eğitimi ve rutin tedavi alırken, kontrol grubu (n=19, ortalama yaş 10,60±3,80, %42 kadın) sadece rutin tedavi aldı. Kaba Motor Fonksiyonel Sınıflandırma Sistemi seviyeleri I-III arasında ve spastisite seviyeleri Modifiye Ashworth Ölçeği'ne göre "0" ile "1+" arasında olan çocuklar çalışmaya dahil edildi. Üst ekstremite hareket açıklığı (EHA), kavrama ve çimdik gücü, el becerileri (Minnesota Manual Dexterity Test (MMDT)) ve fonksiyonel yetenekler (Childhood Health Assessment Questionnaire (CHAQ)) tedavi öncesi ve sonrasında değerlendirildi.
Bulgular: Çalışma grubunda omuz fleksiyonu (p=0,004) ve abdüksiyon (p=0,01), supinasyon (p=0,019) ve bilek fleksiyonu (p=0,004) ve ekstansiyon (p=0,00) EHA değerleri; bilateral MMDT puanları (p=0,003) kontrol grubuna göre istatistiksel olarak anlamlı şekilde gelişti.
Sonuç: Görsel geribildirim eğitimini serebral palsi tanısı ile rehabilitasyon uygulanan çocukların tedavi programına eklemenin üst ekstremite EHA ve el becerileri gibi bazı sonuç ölçümlerinde etkili olduğu bulundu. Uzun süreli rehabilitasyon sürecinde bu yeni yöntem çocuklar, aileler ve fizyoterapistler için tedaviye eklenebilecek alternatif bir seçenek olabilir.
Anahtar kelimeler: Serebral palsi, Üst ekstremite, Rehabilitasyon, Geribildirim.

1: Marmara University, Institute of Health Sciences, Department of Physiotherapy and Rehabilitation, Istanbul, Türkiye.
2: Marmara University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Istanbul, Türkiye.
Corresponding Author: Dilara Merve Sari: dilaramervesari@gmail.com
ORCID IDs (order of authors): 0000-0001-7443-3747;0000-0002-3263-2278
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Cerebral Palsy (CP) is a permanent motor function, posture and movement disorder and sometimes sensory-perception, behavior, learning, speech and language problems are also included in this picture.[1] In the United States of America, the prevalence of CP was found to be 2.6 per 1000[2], whereas in eastern Denmark it was found to be approximately 1.7 per 1000.[3]

Approximately 80% of spastic hemiparetic and quadriplegic cases have significant upper limb problems.[4] Upper limb functions are important for children with CP to be independent in their daily life. The main aim of rehabilitation is to solve problems such as being able to take care of themselves, provide personal hygiene, be able to eat or drink, improve cosmetic appearance, control involuntary movements, reduce spasticity and provide body balance.[5]

One of the most used rehabilitation methods in CP is Bobath's neurodevelopmental therapy (NDT) method. This method aims at operating different internal activities to coordinate motion and balance in a continuous way. It works by learning functionality which involving sensorial, perceptive, and adaptive components and it is an individualized approach aiming at improving motor function in people with neurological problems such as CP and improving their independence in a variety of contexts. In this method, it is thought that stimulating the affected side will promote the desired muscle action to be performed in everyday activities by correcting abnormal movements patterns.[6]

Throughout daily life, body movements are altered in response to changing hints-feedbacks. For example, when reaching for a target object human brain uses visual information about the location of the object and information about the current body position and how the body is going to move. All this information is received and processed constantly and instantly and creating a continuous feedback loop where the brain transforms the information received into the correct and precise muscle response. The absence of clear visual feedbacks can cause inaccurate or inappropriate movement. The feedback responses that control movement are calculated by the brain not from a single signal, but from multiple sources of sensory information including vision, posture, and sense of self-movement.[7]

Woollacott and Shumway-Cook[8] stated that various feedback methods should be used for learning to take place. Feedback makes learning a new task easier, increases performance, and makes the activity more fun.[8] With the improvements in technology, more technological devices or systems with visual and/or auditory feedback are being used in the rehabilitation.[9]

People with cerebral palsy seem to participate in regular physical activity less than their aged-matched peers despite the known health benefits. It has been known that exercising is promoted for CP but with an increase in age there is a decrease in physical activity observed in children with CP. Therefore, there is a need to find new methods to keep children and adolescents with CP motivating to exercising.[10]

The purpose of this study was to investigate if visual feedback training (VFT) added to the usual therapy is effective on upper limb functions in children with CP.

METHODS

Study design and participants

Children with CP, who applied to Dilbade Education and Rehabilitation Center between January 2018 and February 2018 for rehabilitation, were invited to participate in this study (Figure 1). A prospective randomized trial was undertaken between January 2018 and May 2018. Ethical approval was obtained from Marmara University Faculty of Medicine Clinical Research Ethics Committee (with the approval number: 09.2018.007 on 05.01.2018) (clinicaltrials.gov registry: NCT03726385) and this study was conducted in accordance with the Declaration of Helsinki. Oral and written information were provided on aim, duration, and interventions of the study to the legal representatives of the children prior to the study enrollment without offering any incentives. Hereafter, the volunteered participants were assessed by the principal investigator before the treatment and were randomly assigned into two groups stratified by sex and age using a random numbers table determined by the randomization program on the Research Randomizer website (http://www.randomizer.org).

Children diagnosed with CP and aged

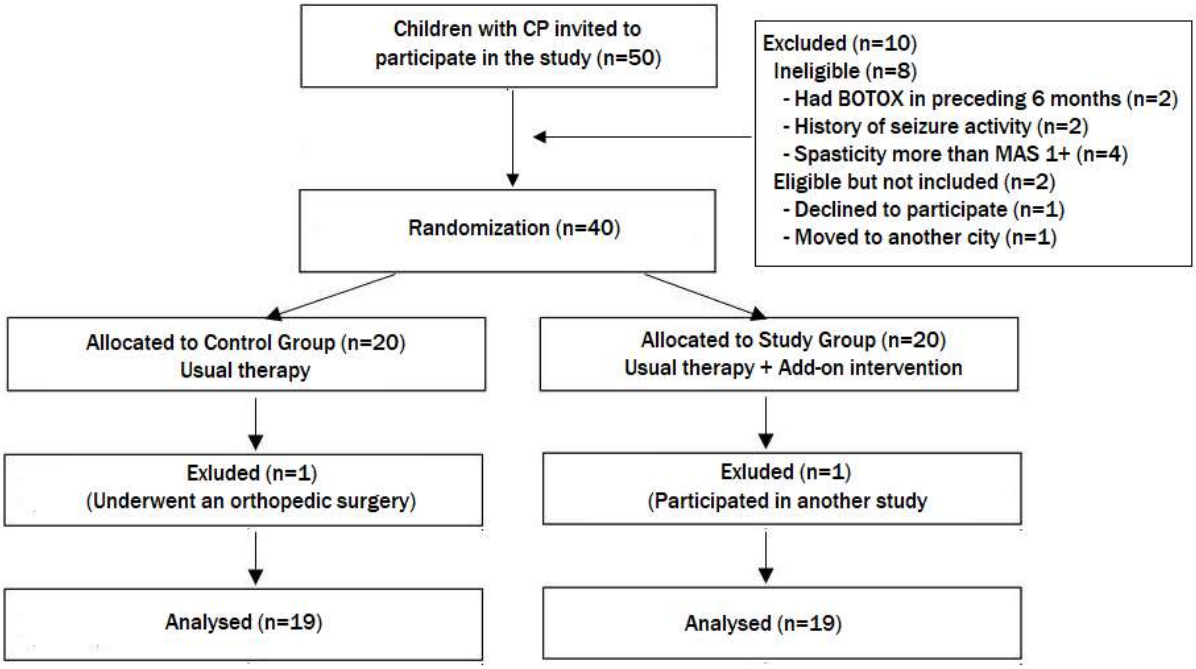

Figure 1. Flowchart of the study.

between 4-18 years were included in the study. Children having upper limb spasticity level more than '1+' according to the Modified Ashworth Scale (MAS),[11] having any congenital deformity in the upper limbs, cardiac or orthopedic discomfort, visual or hearing defect and being unable to cooperate with the exercises, having any history of seizure activity, had Botulinum Toxin (BOTOX) injection in upper limbs within preceding 6 months, with Gross Motor Function Classification System (GMFCS) level IV or V[12] were excluded from the study.

Outcome measurements

All evaluations were applied before and after the study and collected data were noted in the participants follow-up form. Range of motion (ROM) of the joints in the upper limb was measured with a universal goniometer in the standard position.[13]

Hand grip strength was measured by the Jamar hand dynamometer (The Jamar Company, Inc., USA) recommended by the American Society of Hand Therapists (ASHT).[14] Measurements were repeated three times in the 2nd range of the dynamometer. The mean value of the measurements was recorded in the form in kilogram-force (kgF) unit.

Saehan pinch meter (Saehan Corporation, South Korea) was used in the evaluation of the tip, lateral and three-point pinching strength. The measurement position proposed by ASHT was used.[15] The measurements were repeated three times, the rest period was 15 seconds between each measurement and the mean of the three measurements was noted.

Hand skills were assessed with Minnesota Manual Dexterity Test (MMDT) which is a standardized test evaluating the subject's ability to move small objects to various distances. The total seconds spent completing the task is the score obtained from the test.[16]

Childhood Health Assessment Questionnaire (CHAQ) was used for the assessment of functional abilities. The questionnaire has 8 domains of physical function (30 items) to assess functional abilities. The mean score of the eight domains finally makes up the disability index and ranges from 0 (no disability) to 3 (disabled).[17]

Treatment program

All participants in the present study were treated at the same rehabilitation center twice a week for 8 weeks, 16 sessions in total. The total duration of each therapy session was 45 minutes. Control group received only usual

Figure 2. Upper limb training with turning impellers.

Figure 3. Upper limb training with passing a shoelace through the holes.

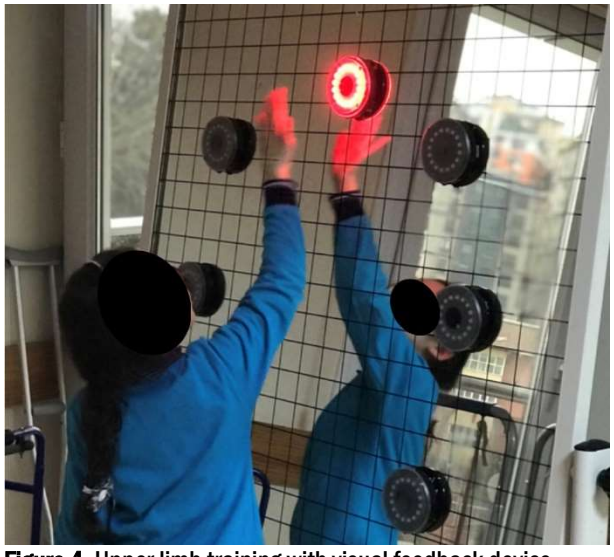

Figure 4. Upper limb training with visual feedback device.

therapy whereas the study group received usual therapy (for 35 minutes in each session) and add-on intervention. Add-on intervention was VFT with Cogniboard® Light Trainer device (for 10 minutes in each session) and the usual therapy consisted of NDT-based rehabilitation program.

Neurodevelopmental therapy (NDT) based upper limb rehabilitation

All participants received usual therapy consisting of NDT-based rehabilitation program. This program was determined according to the age, sex, mental status, and preferences of the individuals. The program included rehabilitation of muscle tonus disorders, sensory-perception-motor integrity enhancement, exercises to increase upper limb functions (Figure 2-3), stretching and strengthening exercises due to muscular shortness and weakness, exercises to accommodate movements in daily life, and training of activities such as standing up, eating, walking and body care.

The add-on intervention

Upper limb training with visual feedback was applied for 10 minutes as add-on intervention after getting 35 minutes of usual therapy in the study group. The devices were placed on the mirror and participants were asked to keep turning the lights off by holding the hand in front of each lightening device. The distance between the participants and the mirror was set proportionally to their height. For children between 100-149 cm of height the distance was set to 40 cm whereas, for the children between 149-175 cm the distance was set to 50 cm. Eight devices were placed on the mirror within the reach of the participants (Figure 4).

Statistical analysis

The statistical program Statistical Package for Social Sciences (SPSS) Version 11.5 (SPSS Inc., Chicago, IL, USA) was used in the data analysis of the study. The p-value of $p<0.05$ was statistically significant in the data analysis. Shapiro-Wilk test was used to investigate if the variables were appropriate to normal distribution. In the comparison of the nominal characteristics of the participants in both groups, such as gender, type of CP, affected limb, occurrence term of the problem, use of assistive devices, and GMFCS level the Fisher Precise Chi-Square Test was used. The initial

demographic characteristics such as age, height, weight, body mass index (BMI) of the participants in both groups and the changes before and after the treatment were compared with the Independent Samples t-Test and Paired Samples t-Test.

RESULTS

A total of 50 children with CP were invited to participate in the study, of these children 40 (19 girls, 21 boys) of them participated in this study. The clinical study flow is presented in Figure 1. The demographics and clinical characteristics of the participants are shown in Table 1. When the initial evaluations of the groups were compared, statistically significant differences were obtained in weight, Body Mass Index (BMI), duration of total treatment (DTT), GMFCS, hand grip values, and CHAQ scores ($p<0.05$) (Table 1).

Group data for all applied evaluations, within-group differences, between-group differences, and comparison of occurred differences between groups are presented in Table 2. When before and after the study evaluations were compared; there was a statistically significant difference ($p<0.05$) in shoulder flexion and abduction, elbow flexion, supination and pronation, wrist flexion and extension; hand grip, lateral and three-point pinch measures and MMDT unilateral and bilateral test scores of the study group. For the control group, there was a statistically significant difference ($p<0.05$) in hand grip, lateral and three-point pinch values and unilateral MMDT scores.

Upon comparing the differences occurred after the study in groups; a statistically significant difference ($p<0.05$) was found between shoulder flexion and abduction, supination, wrist flexion and extension ROM and bilateral MMDT scores (Table 2).

DISCUSSION

This study aimed to investigate if upper limb training using VFT added to the usual therapy is effective on upper limb functions in children with CP in means of children's upper limb ROM, muscle tone, grip and strengths, and functional abilities. There was a trend for more increase in shoulder flexion and abduction, supination, wrist flexion and extension ROM values and bilateral MMDT scores in study group compared to the control group.

Motor, sensory, orthopedic, and cognitive problems experienced by children with CP significantly limit their independence in daily life activities. Due to affected motor disorders gripping and limitations in the joint movements inhibit the lives of children. Along with these problems, it also affects the use of assistive devices for walking. For these reasons, upper limb problems are one of the main issues to be emphasized in the rehabilitation of CP to sustain their daily lives more independently.

In the literature, the duration of treatment has been reported mostly to be 8 weeks, in terms of the efficacy of treatment in children with CP.[18,19] In the present study, each session was 45 minutes in total, considering sustaining attention and the children's cooperation. Control group received 45 minutes of usual therapy whereas study group received 35 minutes of usual therapy plus 10 minutes of VFT. Therapies were applied twice a week, 16 sessions in total which were determined considering the similar studies in the literature.[20]

At the end of the second trimester of prenatal life, most human neurons are composed. Synapse formation is very fast until 6 years of age. There is a gradual decrease in the number of synapses from the age of 14 years, and this decrease continues lifelong.[21] Based on this information, children between 4 and 18 years old were included in the study, the range of age with rapid synapse formation and brain reorganization. Children under the age of 4 and above 18 years of age were not included in the study.

Studies on motor skills involving dense and multi-repeat sensory motor stimuli are important for the long-term sustainability of brain plasticity. The change in the cortical map increases with the increase in the experience-training level due to synaptogenesis and the increase in synaptic connections. With various hand activities, cortical connections are strengthened and reshaped with experience.[22] The NDT method is based on the principles of motor learning. In the literature, it is one of the most widely accepted therapy method in the rehabilitation of children with CP, and in

Table 1. Demographics, clinical characteristics, and initial evaluations of the participants.

	Study Group (n=19)	Control Group (n=19)	
	X±SD	X±SD	p
Age (years)	8.5±3.4	10.6±3.8	0.087
Height (m)	1.3±17.1	1.4±19.7	0.235
Body weight (kg)	30.7±11.4	42.2±15.2	0.014*
Body mass index (kg/m²)	17.1±3.9	20.5±4.6	0.019*
	n (%)	n (%)	
Gender (Female/Male)	10/9 (53/47)	8/11 (42/58)	0.516
Type of cerebral palsy			
Hemiplegic	16 (85)	6 (32)	
Diplegic	2 (10)	11 (58)	0.492
Tetraplegic	1 (5)	2 (10)	
Affected limb (Right/Left)	12/7 (63/37)	12/7 (63/37)	1.000
Occurrence term of the problem			
Prenatal	3 (16)	3 (16)	
Perinatal	15 (79)	13 (68)	0.565
Postnatal	1 (5)	3 (16)	
Use of assistive devices			
Ankle-foot orthosis	9 (47)	11 (58)	
Insole	6 (32)	2 (10)	
Twister	1 (5)	1 (5)	0.185
Walker	- (0)	1 (5)	
Immobilizer	- (0)	2 (10)	
GMFCS (Median (min-maks))	1 (1-3)	2 (1-3)	0.022*

*p<0.05. GMFCS: Gross Motor Functional Classification System.

Table 2. Outcome measures and comparison of the differences occurred between pre- and post- evaluations.

	Study Group (n=19)			Control Group (n=19)					
	Before	After		Before	After		Study G.	Control G.	
	X±SD	X±SD	p[a]	X±SD	X±SD	p[a]	Δ±SD	Δ±SD	p
ROM (degrees)									
Shoulder flexion	176±5	179±2	*	165±24	166±24		4±4	0±2	*
Shoulder abduction	176±6	179±3	*	157±34	157±34		3±5.0	0±2	*
Elbow flexion	138±3	140±0	*	136±7	137±7		2±3	1±2	
Elbow extension	0±1	0±1		-2±7	-2±7		0±0	0±0	
Supination	86±8	90±0	*	76±21	76±22		4±8	0±2	
Pronation	86±13	88±10	*	84±13	87±8 90.		2±3	3±1	
Wrist flexion	87±3	88±9	*	82±14	82±13		1±10	0±3	*
Wrist extension	66±7	70±0	*	68±7	70±7		4±3	0±1	*
Hand strength (kgF)									
Grip	7±3	8±4	*	11±7	13±7	*	1±1	2±2	
Tip pinch	1±1	1±1		1±7	2±1		0±1	0±0	
Lateral pinch	2±1	2±1	*	3±1	3±2	*	0±1	0±0	
Three-point pinch	1±1	2±1	*	2±1	2±1	*	0±0	0±0	
MMDT (seconds)									
Unilateral	339±179	312±168	*	302±215	287±216	*	27±34	15±33	
Bilateral	254±108	224±99	*	265±164	265±176		30±39	0±30	*
CHAQ scores	1±1	1±1		2±1	2±1		0±0	0±0	

*p<0.05. p[a]: before vs after treatment. CHAQ: Childhood Health Assessment Questionnaire. MMDT: Minnesota Manuel Dexterity Test. ROM: Range of motion. Δ: Mean difference between pre-and post-evaluations.

comparative studies where the efficacy of new approaches to rehabilitation programs are examined the NDT method is recommended to be applied in the treatment of the control group.[23] Many researchers state that virtual rehabilitation programs added to NDT based rehabilitation programs are also useful.[10,24] With this information, NDT was preferred to be applied as an evidence-based method to both groups as the usual therapy in this study.

Mackey and et al. researched upper limb movement deficits in children with hemiplegia using 3-dimensional kinematic analysis of functional tasks and they reported that children with hemiplegia have significantly less supination and shoulder flexion and increased compensatory trunk flexion and restriction in elbow extension.[25] The present study shows that shoulder flexion and abduction, supination and wrist flexion and extension ROM values increased more in study group compared to control group. Based on the results, it is thought that the addition of the VFT to usual therapy has a positive effect on shoulder flexion and abduction, supination and wrist flexion and extension. These results can be explained by the fact that the VFT mainly involves the elongation activities in the upper limbs, hence repeated activities of wrist flexion, shoulder flexion, and abduction.

In this study, a hand dynamometer and a pinch meter was used to measure hand grip and pinch strength. A significant improvement was observed in hand grip, lateral and three-point pinch strength whereas no significant difference was seen in tip pinch strength in both groups. The reason for observing similar changes in the grip and pinch strengths can be explained by the application of usual therapy in both groups, and due to the lack of grip and pinching activities in VFT in the study group. Also, children with CP are generally in favor of using their less affected upper limb in daily activities and do not have much opportunity to learn and develop motor skills in the more affected upper limb because of the non-use.[26] Chiu et al.[10] investigated the effectiveness of Wii Sports Resort™ games on upper limb functions in children with CP and reported that a high number of repetitions while holding the Wii remote may have contributed to a potential benefit in grip strength. To develop the strength of gripping and pinching; the therapy program should include more activities of gripping and pinching.

In the evaluation of hand skills, the MMDT was chosen because of its distinctive ability to measure handgrip skills. It is a constantly preferred test to evaluate both extremities unilaterally and bilaterally in neurological cases; a speed and endurance-oriented test for evaluating upper limb functions.[27] After the treatment, significant improvements were observed in both MMDT scores in study group whereas a significant increase only in the unilateral score was obtained in control group. When the change in unilateral MMDT scores were compared between the groups, the change in the MMDT completion time of the study group was higher than that of the control group, and the difference between the groups was statistically significant. Based on this information, it can be said that adding VFT to the usual therapy causes more changes in bilateral MMDT scores and VFT increases the bilateral hand skills of the individuals. Hutzler et al.[27] investigated the effect of strengthening exercises added to the NDT method on hand, wrist strength, functionality, and daily life activities in 17 patients with CP. They used the MMDT as a pre- and post-treatment evaluation and reported significant changes in the unilateral and bilateral results.

Morales et al.[28] stated that CHAQ is a valid and reliable scale developed to evaluate functional capacity and independence of children with CP. In the present study, there was no statistically significant change in CHAQ's scores in both groups. The reason for this absence of statistically significant changes in CHAQ scores is thought to be the limited study time and presence of good CHAQ scores in the pre-treatment of children participating in the study, having a high functional level before the treatment. There was not any relevant study available to compare the results with the present study.

Upper limb rehabilitation is needed in almost all areas involving physiotherapy and rehabilitation. The main objective of rehabilitation is to regain the patients' capacity to perform skills through practice, training, and experience, and to create permanent behavioral changes. For a successful upper limb rehabilitation, it is necessary to ensure the active participation of the patient and to provide intensive repetitive training in different

conditions. The repetitions contribute to the improvement of performance where a specific task is repeated in the same environmental conditions. On the contrary, to improve motor learning, repetitions should be done with different environmental conditions and diversity. Physiotherapists should help patients develop problem-solving skills in the means of motor problems and to provide the vision to adapt these skills to different conditions.[6,29]

One of the recent popular therapeutic approaches that has been used in CP to enhance upper limb function is action observation therapy (AOT). AOT is a rehabilitation technique, which involves observation of purposeful actions with the intention to imitate and then perform those actions as observed. For example, the patient is asked to observe an action carefully on a video-clip and imitate the movement after the observation. This may include the mirror neuron system processes on the upper limb function resulting from the observation of actions (new motor skills) and actual execution of similar neural structures. AOT was found to be a better rehabilitation technique with the findings of the recent studies for the rehabilitation of the upper limbs to improve physical function and structure, activities, and participation of children with hemiplegic CP than the simple motor training.[30]

Technology is developing every day in health-related fields. The use of technology in rehabilitation is reported to offer a wide range of activities by providing appropriate motor learning and ability to adjust the intensity of stimuli and feedback.[31] In the present study, the intensity of the activities performed in the upper limb rehabilitation with VFT is consistent with the literature in terms of providing frequent repetition, high motivation and making the treatment fun and providing innovation in rehabilitation to the patients and therapists.[31]

Therapists try to keep the patients' interest in the therapy constantly high during the therapy sessions. New technological approaches developed according to the children's characteristics and preferences can be used to provide a variety of treatment options. Some technological devices are sensitive and can transfer the data obtained during the session to the therapist immediately. Innumerable repetitive movements are executed by the device, and it may facilitate the therapist's efforts rather than changing them. There should be a collaborative design between the device and the clinician so that, during the session the therapist can start an easy-to-use device. Portable devices that are at low cost can increase accessibility to technology in the field of rehabilitation.

The participants in study group reported that they found VFT entertaining and one of the participants in study group reported that she started to have more trust in her affected hand after the therapy. There were no adverse events such as seizure activity or loss of balance observed, nor did any of the participants fall during the study.

Limitations

The variation of CP types in the present study was one of the limitations and the variability of CP type has been reported as a similar limitation in many studies in the literature. The evaluation of psychosocial and motivational factors that may have affected the treatment during the study, could be seen as another limitation. Evaluating these factors in future studies can provide important contributions to rehabilitation outcomes.

Additionally, the randomization was not fully concealed. Although the allocation sequence was generated by computer before beginning of data collection and the principal investigator was blinded to the group allocation, it was not hidden to the principal investigator at the after-therapy evaluations. The same physiotherapist (principal investigator) applied all evaluations before and after therapy and her being not blinded at the final evaluations and her being not assessed for inter-reliability might have caused a limitation. Also, the duration of the study and the effectiveness of therapies not being assessed separately or nor having compared to different exercise approaches and practices may have caused limitations.

Conclusion

The present study is the first investigation of the Cogniboard® Light Trainer's effectiveness which is a VFT device in children with CP on upper limb functions. The strong and innovative aspect of our study is that it includes a technological application that increases interest and motivation in children. It can be concluded that the addition of the VFT to the usual therapy program, may enhance treatment success and treatment compliance. In the long-term

rehabilitation process, this method might be an alternative option to be added to the therapy program for children, families, and physiotherapists.

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Authors' Contributions: DMS: Study design, data collection, literature search, writing; **TKÇ:** Study design, idea development, data analysis, project management.

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Conflicts of Interest: *None*

Ethical Approval: The protocol of the present study was approved by the Marmara University Faculty of Medicine Clinical Research Ethics Committee (issue: 09.2018.007 date: 05.01.2018).

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