The effect of somatosensory perception and proprioception on upper extremity functional skills in children with hemiparetic and diparetic cerebral palsy

Hemiparetik ve diparetik serebral palsili çocuklarda somatosensoriyel algı ve propriyosepsiyonun üst ekstremite fonksiyonel becerilerine etkisi

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Abstract

Aim: The aim of the current research is to determine the impacts of somatosensory perception and proprioception on upper extremity functional skills in children with hemiparetic and diparetic cerebral palsy (CP).

Methods: Children with hemiparetic (n=15) and diparetic (n=15) CP at Gross Motor Function Classification System (GMFCS) I-III and Manual Ability Classification System (MACS) I-III levels and healthy children (n=15) with a mean age of 10.71± 4.09 were enrolled in the research. Somatosensory perception was evaluated with the Ayres' Southern California Sensory Integration and Praxis Test (SIPT) sub-parameters, kinesthesia (KIN), touch stimulus localization (TSL), double-touch stimulus localization (DTL), finger recognition (FR), and right-left discrimination (RLD) tests. Proprioception measurements were performed with a goniometer on the shoulder, elbow, and hand-wrist. Upper extremity functional skills were evaluated by the Jebsen-Taylor Hand Function Test (JTHFT).

Results: Somatosensory perception and proprioception of the control group were determined to be significantly better than those of both groups with CP ($p<0.05$). The somatosensory perception, proprioception, and JTHFT test results of children with CP were significantly better in the hemiparetics in comparison with the diparetics ($p<0.05$).

Conclusion: The study showed that children with CP had lower somatosensory perception levels in their upper extremities and had proprioceptive losses in their upper extremities in comparison with their healthy peers. It was shown that diparetic children had lower scores than hemiparetic children in somatosensory perception and proprioception tests compared to their healthy peers.

It was determined that children with CP had lower hand skills compared to their healthy peers and hemiparetic children were better than diparetic group in hand skills. It was revealed that children with CP had lower manual dexterity than their healthy peers, and hemiparetic children had better skills than the diparetic group.

Keywords: Cerebral palsy; hand; perception; proprioception

Öz

Amaç: Bu çalışmanın amacı hemiparetik ve diparetik Serebral Palsi (SP)'li çocuklarda somatoduyusal algı ve propriosepsiyonun üst ekstremite fonksiyonel becerilerine etkilerini belirlemektir.

Yöntemler: Çalışmaya yaş ortalamaları 10,71± 4,09 olan, Kaba Motor Fonksiyon Sınıflama Sistemi (GMFCS) 1-2 ve 3 ile El Beceri Sınıflama Sistemi (MACS) 1-2-3 düzeyindeki 15 hemiparetik SP'li çocuk, 15 diparetik SP'li çocuk ve 15 sağlıklı çocuk (24 erkek/21 kız) dahil edildi. Somatoduyusal algı Ayres Güney Kaliforniya Duyu Bütünleme ve Praxis Testi (SIPT)'nin alt parametreleri olan kinestezi, dokunma uyarısının lokalizasyonu, çift dokunma uyarısı lokalizasyonu, parmak tanıma ve sağ-sol ayırımı testleriyle değerlendirildi. Propriosepsiyon değerlendirmesi için omuz, dirsek, el-el bileğine gonyometrik ölçümü yapıldı. Üst ekstremite fonksiyonel becelerileri Jebsen Taylor El Fonksiyon Testi (JTEFT) değerlendirildi.

Bulgular: SP'li çocuklar ile kontrol grubu arasında somatoduyusal algı ile propriosepsiyonun farklı olduğu ve bu parametrelerin de el becerileriyle anlamlı olarak ilişkili olduğu bulundu ($p<0.05$). Kontrol grubunun somatoduyusal algı ve propriosepsiyonlarının SP'li gruplara göre anlamlı düzeyde daha iyi olduğu bulundu ($p<0.05$). SP'li çocukların somatoduyusal algı, propriosepsiyon ve JTEFT testlerinde; hemiparetik grubun diparetik gruba göre anlamlı düzeyde daha iyi olduğu bulundu ($p<0.05$).

Sonuç: SP'li çocukların sağlıklı yaşıtlarına göre üst ekstremitelerinde daha düşük somatosensoriyel algı düzeylerine sahip olduğu ve üst ekstremitelerinde propriyoseptif kayıpların olduğu belirlendi. Sağlıklı akranlarına göre somatosensoriyel algı ve propriyosepsiyon testlerinde diparetik çocukların hemiparetiklerden daha düşük skorlarının olduğu gösterildi. SP'li çocukların sağlıklı akranlarına göre daha düşük el becerilerine sahip oldukları, hemiparetik çocukların ise diparetik gruba göre daha iyi düzeyde olduğu belirlendi.

Anahtar Sözcükler: Algı; üst ekstremite; propriyosepsiyon; serebral palsi

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INTRODUCTION

Cerebral palsy (CP) represents a non-progressive neurodevelopmental disorder characterized by posture and movement disorders due to perinatal brain injury (1). Hence, sensory-motor impairment, which takes place under the influence of systems including proprioception, tactile, and vestibular systems, is the primary problem in CP (2, 3).

The somatosensory system is active from the early stages of life and plays an important role in sensory-motor development. The tactile sense develops the earliest among all senses (4). The somatosensory system is very important in gross and fine motor development. Infants use tactile cues to reach an object throughout their lives, even at the early stages of life. Correct tactile and proprioceptive sensory input is crucial for motor development during childhood and is especially significant for fine motor development during the preschool period (5).

Research has indicated that children with CP have impaired tactile discrimination skills (5). This impairment is closely related to motor losses. It has been observed that motor skills are also impacted in individuals with impaired somatosensory perception processing and cause significant functional impairments (6). Studies have indicated that children with CP also experience loss of stereognosis, two-point discrimination, and tactile senses (6). As a result of sensory losses, motor learning required for fine hand skills is also delayed and may result in clumsiness, decreased sensitivity, or inability to use extremities in individuals (6). It is known that poor tactile perception will cause functional impairment in children with hemiparetic CP (7). While no difference has been observed in the senses of pain, light touch, and vibration between the affected side and the less affected side in these children, a difference has been detected in tactile, proprioception, and two-point discrimination senses (8). Children with diparetic CP are stated to have poor tactile discrimination skills (9).

Proprioception is the somatosensory system that uses afferent stimuli from muscles, joints, and skin (10). Proprioception is a sense that ensures the sense of joint position, kinesthesia, the perception of the resistance and pressure created by the movement in the joint, and the perception of the body position in space (10). It provides postural control by working with the somatosensory, visual, and vestibular systems. Owing to the somatosensory receptors in the body, appropriate adaptive sensory and motor responses are created by the integration of the senses from the body (11). Loss of proprioception in CP arises from the lesion in the Central Nerve System (CNS) and proprioceptive inputs to the sensory afferent muscle spindle, Golgi tendon organ, joint, and cortex is affected. The most common sensory deficits in CP are stereognosis and proprioception, which are affected bilaterally (3). The superficial sense is usually normal in these children, but the senses of proprioception, stereognosis, and kinesthesia are adversely impacted. Due to these problems, it becomes more challenging for children with functional disabilities in the upper extremity to fulfill their roles in society (12). Difficulties in writing have been observed in children due to loss of proprioception, which has also been associated with poor coordination skills. This leads to difficulties and delays in motor learning while children acquire new skills (12). Sensory inputs take a significant place in developing motor function and acquiring functional independence in children with CP. Deficiencies in sensory input may delay learning new motor movements, which may cause disuse of the extremities and sensitivity (12).

Deficiencies in upper extremity functions due to their involvement are among the most significant factors influencing activities of daily living (ADL) in children with CP (13). Limitations leading to the restriction of normal joint movements due to hypertonia in the upper extremity, loss of grip strength due to isolated finger movements that cannot be performed with a normal pattern, cortical thumb deformity, inadequacies in manipulation skills, and loss of speed and coordinated movement skills are observed in children with CP (13). The aim of the current study is to research the impacts of somatosensory perception and proprioception on upper extremity functional skills in children with hemiparetic and diparetic CP.

MATERIAL AND METHODS

Participants

Children with hemiparetic and diparetic CP who were diagnosed by a specialist physician and presented to the research and treatment unit of SANKO University Physiotherapy and Rehabilitation Department and their families were included in the study. When the sample size was calculated with α=0.05 and power=0.80 in the power analysis, it was decided to include 20±5 children in each group consisting of children diagnosed with hemiparetic and diparetic CP and healthy children. The study was completed with 45 children since there were children who could not participate in the evaluations due to the pandemic and various reasons (Figure 1). Children with hemiparetic and diparetic CP aged between 6-18 who were able to receive verbal commands, did not have any intellectual disability, had Gross Motor Function Classification System (GMFCS) Level≤III, had upper extremity muscle spasticity≤2 in accordance with the Modified Ashworth Scale (MAS), had the Manual Ability Classification System (MACS)≤III, had not undergone surgery or received Botulinum Toxin (Botox) treatment in the last 6 months, and whose family consent was obtained were enrolled in the research. All of the children's parents signed the informed volunteer consent form for this study. Children with joint contractures in the shoulder, elbow, and hand-wrist and any hearing or vision problems were excluded from the study. pproval for the research was received from the SANKO University Non-Interventional Clinical Research Ethics Committee (date: 07.07.2020, decision no: 2020/07), and the study was performed in accordance with the Declaration of Helsinki. The clinical trial number is NCT05213715.

Outcome measures

The children's sociodemographic characteristics were recorded. The somatosensory perception test (touch stimulus localization test (TSL), double-touch stimulus localization test (DTSL), finger recognition test (FR), right-left discrimination test (RLD), Jebsen-Taylor Hand Function Test (JTHFT), Modified Ashworth Scale (MASH), Gross Motor Function Classification System (GMFCS), Manual Ability Classification System (MACS), and goniometer and kinesthesia tests (KIN) in proprioception evaluation were used in all children. A table, chair, and stretcher suitable for the child who was performed were used in all evaluations.

Somatosensory perception assessment: The subtests of Ayres' Southern California Sensory Integration and Praxis Test (SIPT) (touch stimulus localization test, double-touch stimulus localization test, finger recognition test, and right-left discrimination test) were used (14). Before the assessment, the children were explained how the tests would be conducted. Before the test, the children's eyes were closed, or an eye patch was used. All assessments were carried out bilaterally in the following order:

Touch stimulus localization test (TSL): During the test, the child's hand, wrist, and forearm, respectively, were touched once with a pencil first, and he/she was requested to show the touched area with his/her finger. The distance between the place touched with the pencil and the place pointed by the child was measured with a ruler and recorded in centimeters (cm). If the distance between the touched location and the distance touched by the child was far from the touched location, it indicated poor tactile perception (14).

Double-touch stimulus localization test (DTSL): Two different points, left hand-right cheek, right hand-left hand, left cheek-right cheek, left hand-left cheek, right hand-left cheek, and right hand-right cheek, were touched simultaneously with two separate pencils. The child was requested to show both points touched. The total score was written by giving 2 points if the child knew both points, 1 point if he/she knew one point, and 0 points if he/she did not know any of the points. In the scoring in which the best value was measured out of 12, the lower this value was, it was interpreted as the worse tactile perception to the same extent. (14).

Finger recognition test (FR): The child was requested to put his/her hands on the table, and 16 different points (right-left) were touched with a pencil. The child was requested to show the touched points with his/her finger. It was scored as 1 point in case of a correct answer and 0 points in case of an incorrect answer. The total score was acquired by summing the scores of both hands. A higher score indicates good tactile perception (14).

Right-left discrimination test (RLD): The child was asked to repeat 10 commands, respectively: 'Show me with your right hand, touch your left ear, hold this pen with your right hand, touch my right hand, etc' If the correct answer was given in the first three seconds, 2 points were scored; if the correct answer was given in ten seconds 1 point scored; if no answer was given

Table 1. Comparison of demographic information between groups

	Hemiparetic (n:15) mean±SD	Diparetic (n:15) mean±SD	Control (n:15) mean±SD	*Test statistics*	*p*
Age (y)	8.67 ± 3.64	11.87 ± 3.7	11.6 ± 4.37	KW-H=6.718	0.035^{*ac}
Height	1.29 ± 0.12	1.42 ± 0.16	1.5 ± 0.21	KW-H=9.619	0.008^{*ac}
Weight (kg)	28 ± 11.57	40.53 ± 17.33	46.07 ± 16.89	KW-H=9.958	0.007^{*ac}
BMI	16.11 ± 3.4	19.29 ± 4.91	19.64 ± 3.53	F=3.528	0.038^{*ac}
Sex (m/f)	5/10	8/7	11/4	KW-H=4.714	0.003^{*a}
Percent (%)	33.3/66.7	53.3/46.7	73.3/26.7		

*p<0,05; SD: Standart Deviation, n: Number, m: Male, f: Female, F: One way Anova, KW-H: Kruskal-Wallis test, a: Hemiparetic-control, b: Diparetic-control, c: Hemiparetic-diparetic, kg: kilograms, y: year, BMI: Body Mass Index

Table 2. Comparison of categorical variables between groups

	Hemiparetic (n:15)	Diparetic (n:15)	Control (n:15)	X^2	*p*
	n (%)	n (%)	n (%)		
Dominance					
Right	12 (80)	11 (73.3)	11 (73.3)	0.246	0.884
Left	3 (20)	4 (26.7)	4 (26.7)		
Gross Motor Function Classification System (GMFCS)					
1	15 (100)	9 (60)	15 (100)	15.150	***0.001*** **
2	0 (0)	6 (40)	0 (0)		
Manuel Ability Classification System (MACS)					
1	12 (80)	2 (13.3)	15 (100)	33.178	***0.001*** **
2	3 (20)	10 (66.7)	0 (0)		
3	0 (0)	3 (20)	0 (0)		

p<0,01; n: number, %: Percent, X^2:** Chi-square test

Table 3. Comparison of somatosensory perception tests of groups

Somatosensory Perception	Hemiparetic (n=15)	Diparetic (n=15)	Control (n=15)	*Test statistics*	*p*
	mean±SD	mean±SD	mean±SD		
KIN (right)	35.24 ± 7.35	31.86 ± 4.51	39.93 ± 4.95	KW-H=10.301	0.006^{*b}
KIN (left)	34.55 ± 5.83	30.47 ± 5.92	39.35 ± 3.55	KW-H=15.812	0.001^{*ab}
Right-hand touch stimulus localization test (TSL)	6.33 ± 2.4	7.65 ± 2.38	5.01 ± 2.56	F=4.383	0.019^{*b}
Left-hand touch stimulus localization test (TSL)	8.36 ± 3.28	10.14 ± 4.1	6.75 ± 2.8	F=3.646	0.035^{*b}
Double-touch stimulus localization test (DTSL)	13.53 ± 0.92	12.73 ± 1.53	13.8 ± 0.41	KW-H=6.804	0.033^{*b}
Finger recognition (FR)	14.67 ± 1.59	14.33 ± 1.84	15.67 ± 0.62	KW-H=6.962	0.031^{*ab}
Right-left discrimination (RLD)	16.53 ± 2.47	16 ± 3.09	18.47 ± 1.81	KW-H=7.417	0.025^{*ab}

*p<0,05; SD: Standart deviation, F: One way Anova, KW-H: Kruskal-Wallis test, a: Hemiparetic-control, b: Diparetic-control, c: Hemiparet-icdiparetic, KIN: Kinesthesia

Table 4. Comparison of proprioception of the groups

	Hemiparetic (n:15)	Diparetic (n:15)	Control (n:15)	*p*
Shoulder flexion (right)	9 ±5.87	13.06 ± 6.54	6.60± 5.87	***0.026***b*
Shoulder flexion (left)	11± 4.35	15.06± 7.43	7.46± 5.79	***0.009***b*
Shoulder abduction (right)	9.66 ± 5.43	19.93± 8.47	9.93 ± 5.45	***0.002***bc*
Shoulder abduction (left)	12.26 ± 5.72	22.86± 8.02	12± 5.87	***0.000***bc*
Elbow flexion (right)	3.96 ± 3.50	8.30± 5.22	4.76± 4.38	***0.018***c*
Elbow flexion (left)	5.10 ± 3.35	6.63± 4.42	5.63± 5.39	0.623
Elbow extension (right)	4.50 ± 3.72	7.96± 5.46	3.43± 3.43	***0.018***b*
Elbow extension (left)	6.10 ± 4.17	10.70± 7.58	4.43 ± 3.61	***0.023***b*
Supination (right)	4.40 ± 2.13	10.06± 5.56	4.60± 4.38	***0.008***bc*
Supination (left)	6.40± 2.94	11.53± 6.10	3.86± 2.61	***0.001***b*
Pronation (right)	4.60 ± 2.87	9.26± 4.94	4 ± 3.44	***0.003***bc*
Pronation (left)	6.86 ± 4.42	10.26± 4.75	3.66 ± 2.38	***0.001***b*
Wrist flexion (right)	5.80± 3.27	12.60± 6.73	2.73 ± 3.05	***0.000***bc*
Wrist flexion (left)	6.80± 3.07	14 ± 3.44	5.46 ± 3.06	***0.000***bc*
Wrist extension (right)	4± 2.36	7.13± 3.60	2.60 ± 2.66	***0.001***b*
Wrist extension (left)	4.06 ± 2.08	8.13± 3.99	4.13 ± 3.15	***0.006***bc*

*p<0,05, n: Number, Kruskal-Wallis test, a: Hemiparetic-control, b: Diparetic-control, c: Hemiparetic-diparetic

Table 5. Comparison of jebsen taylor hand function test (JTHFT) values between groups

JTHFT	Hemiparetic (n:15)	Diparetic (n:15)	Control (n:15)	*Test statistics*	*p*
	mean±SD	**mean±SD**	**mean±SD**		
Card flip (right)	7.35 ± 1.96	11.21 ± 7.86	4.32 ± 1.18	KW-H=25.084	***0.001***ab*
Card flip (left)	8.91 ± 2.88	12.31 ± 8.69	4.28 ± 0.71	KW-H=28.582	***0.001***ab*
Putting objects in the can (right)	10.57 ± 1.99	14.69 ± 5.41	7.19 ± 1.3	F=18.206	***0.009***abc*
Putting objects in the can (left)	13.21 ± 3.87	16.16 ± 7.42	7.01 ± 1.47	KW-H=27.842	***0.001***ab*
Stacking checkers (right)	6.83 ± 3.3	11.26 ± 8.29	2.66 ± 0.99	KW-H=27.204	***0.001***ab*
Stacking checkers (left)	8.71 ± 5.78	12.19 ± 7.95	2.95 ± 0.88	KW-H=27.331	***0.001***ab*
Move empty cans (right)	7.05 ± 2.49	9.27 ± 4.15	3.43 ± 0.73	KW-H=27.204	***0.001***ab*
Move empty cans (left)	8.29 ± 3.08	10.81 ± 4.69	3.75 ± 1.15	KW-H=27.331	***0.001***ab*
Move full cans (right)	8.72 ± 2.89	10.94 ± 4.94	4.18 ± 1.17	F=15.682	***0.001***ab*
Moving full cans (left)	9.27 ± 4.15	12.32 ± 4.92	4.19 ± 1.18	F=17.742	***0.001***abc*
Picking beans with a spoon (right)	23.34 ± 6.56	34.08 ± 15.67	14.99 ± 11.69	KW-H=18.218	***0.005***ab*
Picking beans with a spoon (left)	31.09 ± 8.07	39.06 ± 18.39	15.31 ± 8.03	KW-H=19.117	***0.001***ab*

*0,05; SD: Standart deviation, n: Number, %: Percent, F: One-way Anova, KW-H: Kruskal-Wallis test, a: Hemiparetic-control, b: Diparetic-control, c: Hemiparetic-diparetic, JTHFT: Jebsen Taylor Hand Function Test

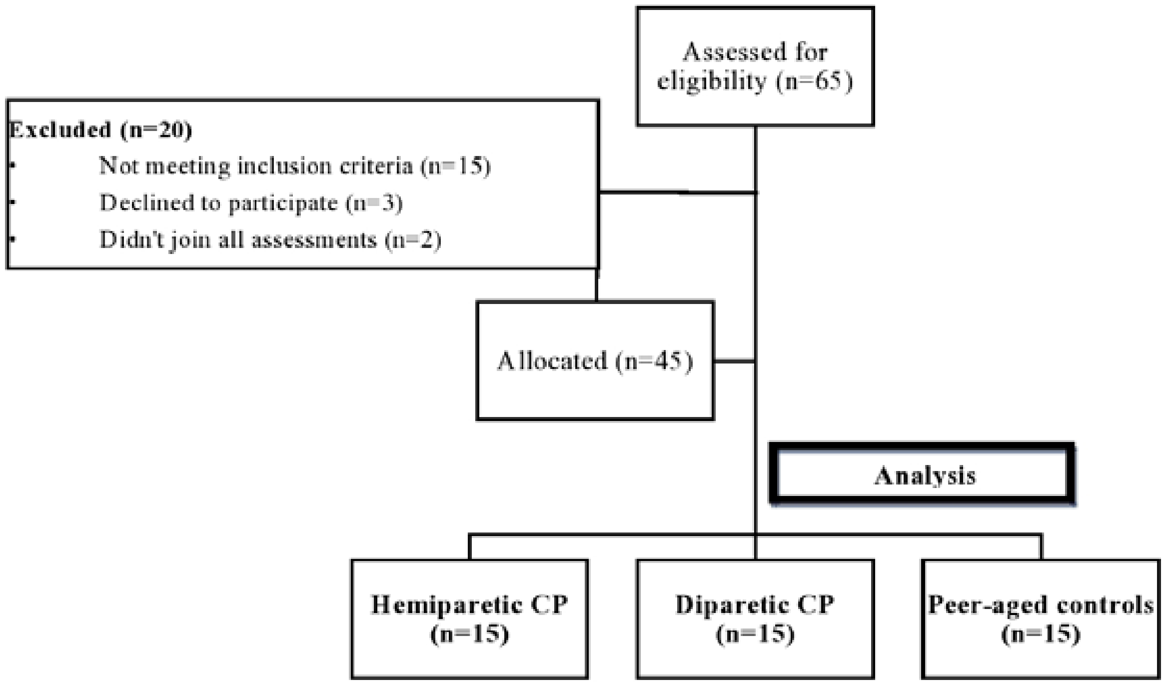

Figure 1. Flow chart showing the experimental design of the study (n: Number)

0 points scored. The total score was recorded by summing all of the questions scored (14).

Jebsen-Taylor Hand Function Test (JTHFT): The JTHFT, which is utilized in the 6-18 age range, comprises 6 subtests that represent hand function in daily life. The application time is 15-45 minutes (min). A scaled board is utilized to ensure a standard arrangement of objects in the test. The time during which all activities are performed is recorded with a stopwatch (15). Activities in the test's sub-parameter are turning over 5 cards, putting 6 objects in a can, stacking 4 checkers, picking up an empty can, picking up a full can, collecting 5 kidney beans with a dessert spoon, and writing. All parameters except writing were measured in this study. Before the assessment, the child was told how to perform the steps in the test. The child started the test with the start command. When he/she finished the activity, the stopwatch was stopped, and the activity completion time was recorded in seconds.

Modified Ashworth Scale (MAS): It is the most frequently used clinical scale for assessing spasticity. It is used to assess muscle tone during passive movement of the muscle in the affected extremity. Muscle tone is scored from 0 to 4 (16). This scale, whose applicability in Turkish has been tested in children with CP, has been determined to be the most effective and reliable method for evaluating spasticity. All of the upper extremity muscles' tone was measured in the supine position.

Gross Motor Function Classification System (GMFCS): It represents a standard classification system for categorizing the gross motor skills of children with CP between levels I and V (17).

Manual Ability Classification System (MACS): It represents a classification system formed in order to classify the hand skills of children with CP aged between 4-18, e.g., grasping and releasing objects in daily life, and how they utilize their hands while holding objects. The MACS is defined at five levels (I-V). Level I shows that the child can grasp and use objects easily and successfully, while Level V demonstrates that the child cannot use objects independently and there is a severe decrease in function performance (18).

Proprioception: The goniometric measurement was used for upper extremity shoulder flexion-abduction, elbow flexion-extension, forearm supination-pronation, and hand-wrist flexion. The child was requested to close his/her eyes or turn the head opposite to the assessed side and perform the movements slowly during the test. First, the physiotherapist showed the movement passively in the full range with the eyes open so that the child could fully perceive the movement. Then, after stopping for 3 seconds at the last point reached, the child returned to the starting position. The child was requested to repeat the same movement. The point at which the child came was measured angularly. Afterward, he/she was asked to do the movement in half range. The physiotherapist showed the same movement of the child in half range. After stopping for 3 seconds at the point reached, the child returned to the starting position. The child was requested to perform the same movement. The angular value of the last point reached was measured. Finally, the difference between the value for the full range and the value for the half range was recorded. Angular values determined for the measurement were evaluated with Kendall McCreary degrees (19).

Kinesthesia test (KIN): This test is one of Ayres' somatosensory perception tests evaluating motion perception. 10 lines are intersecting each other on a 28X43 cm test form, for the right and left hand, in separate directions and of different lengths. The child's eyes were closed, and starting from the right hand, he/she was asked to move his/her index finger of the right hand from the starting point to the end point of every line. Afterward, the child's index finger was placed again at the starting point, and he/she was asked to repeat the movement. The difference in distance between the point where the child ended the movement and the endpoint of the real line was measured using a ruler and recorded. The total value for the right and left acquired was subtracted from 50 and recorded (20).

Statistical analysis

Statistical Package for the Social Sciences package program version 24.0 (SPSS Inc., Chicago, IL, USA was used in statistical analysis. As descriptive statistics, mean±standard deviation values were given for numerical variables, while number and percentage values were given for categorical variables. The conformity of the data to the normal distribution was tested by the Shaphiro-Wilk test, and the Kruskal-Wallis and Dunn's multiple comparison tests were carried out in comparing the non-normally distributed variables in three independent groups, and the one-way ANOVA and LSD multiple comparison tests were employed for the normally distributed variables in three independent groups. The chi-square test was conducted to test the correlation between categorical variables. The correlation between two continuous variables was assessed by Pearson's correlation coefficients. P-value <0.05 was accepted as statistically significant in all measurements.

RESULTS

The mean age of all children in the study (n=45) (hemiparetic (n=15), diparetic (n=15), and healthy control (n=15)) was 10.71±4.09. Of the children, 24 (53.3%) were male, and 21 (46.7%) were female. Upon comparing the demographic data of the children in the research, a significant difference was detected between the three groups concerning age, height, weight, and body mass index (BMI) (p<0.05). In the pairwise comparison of the groups, age, height, weight, and BMI values were revealed to be significantly higher in favor of the control group between the hemiparetic and control groups (p=0.032, p=0.002, p=0.002, p=0.020, respectively). Age, height, weight, and BMI values were determined to be significantly higher in favor of the diparetic group between the hemiparetic and diparetic groups (p=0.02, p=0.046, p=0.035, p=0.036, respectively). The diparetic and control groups were similar in terms of age, height, weight, and BMI (p<0.05) (Table 1).

The three groups were similar in terms of dominant extremity. However, a significant difference was identified between the groups with regard to GMFCS and MACS levels (p=0.001). The GMFCS and MACS levels of the diparetic group were revealed to be significantly lower than those of the hemiparetic and control groups (GMFCS p=0.001, p=0.001, respectively) (MACS p=0.001, p=0.001, respectively) (Table 2).

Upon comparing the somatosensory perception tests of the hemiparetic, diparetic, and control groups, a significant difference was determined between the groups in all sub-parameters (p<0.05). When the groups were compared in pairs, a significant difference was detected between the hemiparetic and control groups in favor of the control group in terms of left-hand KIN, FR, and RLD values (p=0.023, p=0.049, p=0.028, respectively). Upon comparing the diparetic and control groups, a significant difference was observed in favor of the control group in all sub-parameters of the somatosensory perception test (p<0.05). However, no significant difference was revealed in any of the sub-parameters when the hemiparetic and diparetic groups were compared (p>0.05) (Table 3).

Upon comparing the proprioception of all groups, a significant difference was determined between the groups in all parameters except left elbow flexion (p<0.05). In the pairwise comparison of the groups, no significant difference was revealed in any parameter between the hemiparetic and control groups (p>0.05). When the diparetic and control groups were compared, a significant difference was identified in favor of the control group in all parameters except right-left elbow flexion (p<0.05). In the comparison of the hemiparetic and diparetic groups, a significant difference was observed in favor of the hemiparetic group in right-left shoulder abduction, right elbow flexion, right forearm supination, right forearm pronation, right-left wrist flexion, and left wrist extension (p=0.005, p=0.002, p=0.026, p=0.049, p=0.025, p=0.039, p=0.000, p=0.027, respectively) (Table 4).

When the JTHFT completion times were compared, a significant difference was determined between the three groups (p<0.01). The JTHFT test completion time of the control group for all sub-parameters was significantly lower compared to those of the hemiparetic and diparetic groups (p<0.01). In the pairwise comparison of the hemiparetic and diparetic groups, a difference was determined in favor of the hemiparetic group only in the parameters of putting 6 objects in the can with the right hand and displacing 5 full cans with the left hand, among the JTHFT sub-parameters (p=0.002, p=0.032) (Table 5).

DISCUSSION AND CONCLUSION

This study examined the impacts of somatosensory perception and proprioception on upper extremity functional skills in children with hemiparetic and diparetic CP and compared them to their healthy peers. It was determined that children with CP had lower somatosensory perception levels in their upper extremities and experienced proprioception losses in all joints of the upper extremities compared to their healthy peers. In terms of hand skills, it was revealed that children with CP were adversely affected in comparison with their healthy peers, and the hand skills of hemiparetic children were at a better level in some sub-parameters of the JTHFT in comparison with the diparetic group. Concerning somatosensory perception parameters, hemiparetic children were more impacted than their healthy peers in terms of only KIN, FR, and RLD. However, diparetic children were found to be more affected in all somatosensory perception levels than their healthy peers, whereas no difference was detected between the upper extremity somatosensory perception levels of hemiparetic and diparetic children. In terms of upper extremity proprioception, it was seen that children with CP were adversely affected in comparison with healthy children, but proprioception effects in all upper extremity joints of diparetic children were higher than those of hemiparetic children.

As a result of damage to the central nervous system, about 90% of children with CP have tactile and proprioceptive dysfunctions (21, 22). Upon reviewing studies on somatosensory perception, they are observed to focus on children with autism spectrum disorder, and studies on children with CP have not examined the impacts in terms of different clinical types (23, 24). Among the studies in the literature, the research by Megan et al. indicated that most children with hemiparetic CP had poor tactile perception, and as a result, functional disorders were observed (7). A study carried out by Sagner et al. on children with CP revealed that children with CP had poor tactile perception in comparison with the healthy group (9). Cooper et al. found that sensory loss in hemiparetic children was higher than in healthy children, which affected both body halves in hemiparetic children (22). Our study determined that the tactile perception levels of healthy children were better than children with CP in terms of upper extremity somatosensory perception sub-parameters. The results of healthy children in the KIN (left) FR, and RLD tests were better in comparison with hemiparetic children. The difference in kinesthesia on the left was associated with the lower number of children's left-dominant extremity preference.

These results suggested that hemiparetic children who could not recognize fingers and discriminate between right and left might have difficulties perceiving tactile stimuli. All somatosensory perceptions of children with diparetic CP were worse than those of the hemiparetic and control groups. As a result, it was concluded that children with CP perceived tactile stimuli less, and the tactile systems of children with diparetic CP were more impacted. Unlike the literature, this situation demonstrated the importance of conducting upper extremity somatosensory perception tests in clinics for children with diparetic CP in terms of forming evaluation and treatment programs.

Kinesthesia disorder was more common in children with CP (25). Another study using the Ayres kinesthesia test researched the impacts of dance therapy on praxis in children with dyslexia. Dance was found to be significant in the perception of kinesthesia (26). In the present research, it was found that children with CP had worse kinesthetic sense than healthy children. The kinesthetic sense was most affected in the diparetic group. The above-mentioned findings are in line with the literature in that they demonstrate certain levels of kinesthetic losses in different clinical types in children with CP. Evaluation of the upper extremity kinesthetic sense in children with CP of different clinical types will contribute to inadequate studies in the literature.

Studies have shown that children with CP experience losses in proprioception, stereognosis, tactile sense, and two-point discrimination compared to healthy individuals (7, 25). In a study evaluating the proprioception of the upper extremity in children with hemiparetic CP and healthy children, Lewis et al. concluded that children with hemiparetic CP had worse proprioceptive sense than healthy children (27). Duque et al. assessed and compared the senses of pressure, proprioception, and stereognosis in the upper extremity between congenital hemiparetic children and their peers. In conclusion, they reported that pressure, proprioceptive, and stereognosis senses were affected in hemiparetic children (28). Other studies examined elbow proprioception in the goal-directed target-matching task of children with hemiparetic CP and concluded that they made more matching errors in the arm on the affected side (29). In their study carried out with children with CP and healthy children, Hoon et al. found that children with CP experienced losses in their tactile sense and proprioception (30). Our study in which we evaluated proprioception in the upper extremities revealed that healthy children had better proprioception than children with CP, similar to the literature. It was observed that upper extremity proprioception was affected more in children with diparetic CP compared to hemiparetic children. Our study determined that children with hemiparetic CP had better levels of proprioceptive senses in many joints of the upper extremity than healthy children. This is thought to originate from the fact that the dominant hand of hemiparetic children is mostly on the right side and their MACS and GMFCS levels are high. Our study results also differ from the literature in that hemiparetic children, in case of high functional levels and hand skills, can reach proprioception levels similar to their healthy peers when using their dominant hand.

Upper extremity problems in children with CP are among the most important things that adversely affect daily life (13). In children with CP who have deficiencies in hand skills, difficulties are observed in activities requiring the use of both hands when the clinical picture is accompanied by functional and sensory losses in the upper extremity and various postural disorders (31). Accordingly, we think it is important to investigate upper extremity functional skills, somatosensory perception tests, and upper extremity proprioception in children with CP. Identifying deficiencies that affect upper extremity dysfunction with these evaluations may contribute to the rehabilitation programs of pediatric physiotherapists clinically.

Hand functions consisting of gross and fine motor skills are important for a person's independence in ADL. Furthermore, cognitive, motor, and sensory losses adversely affect independence in daily life. Upper extremity involvement is observed in all clinical types, regardless of the clinical type, severity, or distribution of CP. In addition to combined reactions in hemiparetic CP, conditions such as loss of upper extremity function, decreased movement quality, and a slowdown in movement, can be observed, especially with hand-wrist problems (32). In diparetic CP, deficiencies in fine motor skills and decreased endurance are observed in the upper extremities. This adversely affects functionality by revealing abnormal movement patterns in the child. Although children with diparetic and hemiparetic CP have similar upper extremity tone levels, children with hemiparetic CP have slightly more severe deformities and relatively worse motor control than the diparetic group (33). In the literature, it was seen that the proximal regions were usually included in studies evaluating upper extremity skills, and the clinical types of children with CP were mostly spastic hemiparetic children in these studies (29). Studies investigating the functional skills of children with diparetic CP are rare (34). Our study found that the functional skills of children with CP were worse compared to their healthy peers. However, it was observed that children with hemiparetic and diparetic CP did not differ in terms of functional hand skills. The reason for this is thought to be due to the high number of children in the hemiparetic group with better functional levels according to MACS and GMFCS. This demonstrated that children with CP experienced losses of hand skills, independent of clinical type, tone, and deformities. These results indicate that diparetic children should also be evaluated in terms of hand skills.

The study by Elbasan et al. compared children with diparetic CP and their healthy peers and evaluated the independence levels and functional hand skills of these children in daily life. It was observed that children with CP were adversely affected in comparison with the control group in all evaluation parameters (34). Another study evaluated the hand skills of children with hemiparetic CP and healthy peers by the JTHFT. As a result, it was found that the functions and physical properties of hemiparetic CP on the affected side were worse compared to the dominant side of the healthy group in the same age group. In another study assessing hand function in the literature, the JTHFT was used in children with hemiparetic and quadriparetic CP, similar to our study. This study revealed that the hand function of those with hemiparetic CP was better than those with quadriparetic CP, except for the writing parameter, and they completed the tests faster (35). In our study, it was concluded that the hand skills of children with CP were adversely affected compared to their healthy peers, but the hand skills of the diparetic and hemiparetic groups did not differ. In this respect, our results demonstrated the importance of evaluating hand skills not only in the spastic hemiparetic and quadriparetic groups but also in individuals with spastic diparetic CP. It was seen that children with diparetic CP were slower than hemiparetic children in the JTHFT sub-parameter of throwing small objects with the right hand and displacing 5 full cans (left). As a result, it was determined that children with hemiparetic and diparetic CP completed the JTHFT more slowly and in a longer time in comparison with healthy children. Hence, it was concluded that the hand skills of both CP groups were adversely affected compared to their healthy peers (34). In this respect, the results of our study also support the literature, showing that hand skills should be considered important in diparetic children with bilateral spastic involvement as well as in spastic hemiparetic children.

This study suggested that the group with more proprioception involvement had a longer JTHFT time and proprioceptive losses in children with diparetic CP caused a longer JTHFT time. It was found that the JTHFT completion times were shorter since the control group had better proprioception than children with CP. Better proprioception in the hemiparetic group compared to the diparetic group resulted in shorter JTHFT times of the hemiparetic group than the diparetic group. Based on the obtained results, it can be interpreted that proprioception affects hand skills, and the weak proprioception on the affected side in children with CP causes them to not use their hands actively, leading to the decreased quality of movement and a prolongation of its duration. All sensory systems, such as proprioception and somatosensory perception, interact with each other in children with CP. Hence, we think that sensory systems, also including hand functionality in the upper extremity, are impacted, which is an element that should be considered in the evaluation. According to these results, we think that somatosensory perception and proprioception affect functional skills in the upper extremities, and the current study will contribute to the literature in this respect.

This study's limitation is that proprioception measurements were performed using only a goniometer. It has been suggested that the use of advanced proprioceptive measurements such as isokinetic devices in children with CP may yield more objective results. Furthermore, in terms of somatosensory perception tests, detailed evaluations such as the SIPT are recommended to be carried out in children with CP of different clinical types with a higher population in further research. Another limitation of our study is that since the children participating in the study were generally young, the SIPT assessments were done with their eyes closed, and their focusing time was short. Therefore, it is suggested that the test interval time can be extended in future research. In addition, there was a significant difference between the MACS levels of children with CP in this study. However, we believe that the inclusion of homogeneous groups of children with CP with similar MACS levels in further studies may yield more reliable results.

The current study demonstrated that children with CP had lower somatosensory perception levels in their upper extremities than their healthy peers and proprioception losses were observed in all joints of the upper extremity. It was observed that the somatosensory perceptions of hemiparetic children were lower compared to their healthy peers. However, it was revealed that diparetic children were impacted more than their healthy peers in all somatosensory perception levels, whereas there was no difference between the upper extremity somatosensory perception levels of hemiparetic and diparetic children. It was found that children with CP had proprioceptive losses in the upper extremity compared to healthy children, but proprioceptive losses in all upper extremity joints of diparetic children were higher than those of hemiparetic children. The hand skills of children with CP were lower than those of their healthy peers, and hemiparetic children were at a better level in some parameters compared to the diparetic group. It was revealed that the proprioception and somatosensory perception disorders of children with CP adversely affected their hand activities in daily life, and it was also important to evaluate their somatosensory perception levels to increase the level of independence in upper extremity hand functions. Also, this study revealed that more research about somatosensorial and proprioseptive therapy models like sensory integration therapies in children with cerebral palsy should be investigated.

Conflict-of-interest and financial disclosure

The authors declare that they have no conflict of interest to disclose. The authors also declare that they did not receive any financial support for the study.

REFERENCES

1. Morris C. Definition and classification of cerebral palsy: a historical perspective. Dev Med Child Neurol. 2007;49:3-7.
2. Beckung E, Hagberg G. Neuroimpairments, activity limitations, and participation restrictions in children with cerebral palsy. Dev Med Child Neurol. 2002;44(5):309-16.
3. Yardımcı-Lokmanoğlu BN, Bingöl H, Mutlu A. The forgotten sixth sense in cerebral palsy: do we have enough evidence for proprioceptive treatment?. Disabil Rehabil. 2020;42(25):3581-90.
4. Marco EJ, Khatibi K, Hill SS, et al. Children with autism show reduced somatosensory response: an MEG study. Autism Res. 2012;5(5):340-51.
5. Clayton K, Fleming JM. Behavioral responses to tactile stimuli in children with cerebral palsy. Phys Occup Ther Pediatr. 2003;23(1):43-62.
6. Wingert JR, Burton H, Sinclair RJ, et al. Tactile sensory abilities in cerebral palsy: deficits in roughness and object discrimination. Dev Med Child Neurol. 2008;50(11):832-8.
7. Auld ML, Boyd R. Tactile function in children with unilateral cerebral palsy compared to typically developing children. Disabil Rehabil. 2012;34(17):1488-94.
8. Büyükturan B. Spastik diparetik ve hemiparetik serebral palsili çocuklarda alt ekstremite duyu bozukluklarının motor performans üzerine etkilerinin incelenmesi [master's thesis]. Sağlık Bilimleri Enstitüsü; 2012.
9. Sanger TD, Kukke SN. Abnormalities of tactile sensory function in children with dystonic and diplegic cerebral palsy. J Child Neurol. 2007;22(3):289-93.
10. Gandevia SC, Refshauge KM, Collins DF. Proprioception: peripheral inputs and perceptual interactions. Adv Exp Med Biol. 2002;508:61-68.
11. 11. Smania N, Montagnana B, Faccioli S, et al. Rehabilitation of somatic sensation and related deficit of motor control in patients with pure sensory stroke. J Phys Med Rehabil. 2003;84(11):1692-702.
12. Flett PJ. Rehabilitation of spasticity and related problems in childhood cerebral palsy. J Paediatr Child Health. 2003;39(1):6-14.

13. Arner M, Eliasson AC, 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 Am. 2008;33(8):1337-47.
14. Section On Complementary And Integrative Medicine; Council on Children with Disabilities; American Academy of Pediatrics, Zimmer M, Desch L. Sensory integration therapies for children with developmental and behavioral disorders. Pediatrics. 2012;129(6):1186-9.
15. Jebsen RH, Taylor N, Trieschmann RB, Trotter MJ, Howard LA. An objective and standardized test of hand function. Arch Phys Med Rehabil. 1969;50(6):311-319.
16. Bohannon RW, Smith MB. Interrater reliability of a modified Ashworth scale of muscle spasticity. Phys Ther. 1987;67(2):206-7.
17. alisano 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):214-23.
18. 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.
19. Sade A, AS O. Serebral paralizi'de değerlendirme ve tedavi yöntemleri, 2. baskı. Ankara: Hacettepe Üniversitesi Fizik Tedavi ve Rehabilitasyon Yüksekokulu Yayınları; 1997:1-18.
20. Ayres AJ. Southern California sensory integration tests manual. Western Psychological Services. 1980:35-43.
21. Ayres AJ, Tickle LS. Hyper-responsivity to touch and vestibular stimuli as a predictor of positive response to sensory integration procedures by autistic children. Am J Occup Ther. 1980;34(6):375-81.
22. Cooper J, Majnemer A, Rosenblatt B, Birnbaum R. The determination of sensory deficits in children with hemiplegic cerebral palsy. J Child Neurol. 1995;10(4):300-9.
23. Bhojne USHA, Rege PV. A preliminary study of somatosensory abilities of normal school going children and cerebral palsy children in the age group 6–8 years. Indian J Occup Ther. 2001;33(1).
24. Riquelme I, Montoya P. Developmental changes in somatosensory processing in cerebral palsy and healthy individuals. Clin Neurophysiol. 2010;121(8):1314-20.
25. Wingert JR, Burton H, Sinclair RJ, Brunstrom JE, Damiano DL. Joint-position sense and kinesthesia in cerebral palsy. Arch Phys Med Rehabil. 2009;90(3):447-53.
26. Doğan FZ, Akel BS. Disleksili Çocuklarda Dans Hareket Terapisinin Praksis Üzerindeki Etkisi; Vaka Serisi Çalışması. Ergoterapi ve Rehabilitasyon Dergisi. 2021;9(1):41-8.
27. Lewis CA, Goble DJ, Hurvitz EA, et al. Sensorimotor Coordination in Children With Hemiplegic Cerebral Palsy. Arch Phys Med Rehabil. 2005;86(9):e37.
28. Duque J, Thonnard JL, Vandermeeren Y, Sébire G, Cosnard G, Olivier E. Correlation between impaired dexterity and corticospinal tract dysgenesis in congenital hemiplegia. Brain. 2003;126(Pt 3):732-47.
29. Goble DJ, Hurvitz EA, Brown SH. Deficits in the ability to use proprioceptive feedback in children with hemiplegic cerebral palsy. Int J Rehabil Res. 2009;32(3):267-9.
30. Hoon AH Jr, Stashinko EE, Nagae LM, et al. Sensory and motor deficits in children with cerebral palsy born preterm correlate with diffusion tensor imaging abnormalities in thalamocortical pathways. Dev Med Child Neurol. 2009;51(9):697-704.
31. Sköld A, Josephsson S, Eliasson AC. Performing bimanual activities: the experiences of young persons with hemiplegic cerebral palsy. Am J Occup Ther. 2004;58(4):416-25.
32. Tomhave WA, Van Heest AE, Bagley A, James MA. Affected and contralateral hand strength and dexterity measures in children with hemiplegic cerebral palsy. J Hand Surg Am. 2015;40(5):900-7.
33. Law K, Lee EY, Fung BK, et al. Evaluation of deformity and hand function in cerebral palsy patients. J Orthop Surg Res. 2008;3:52.
34. Elbasan B, Bozkurt E, Oskay D, Oksuz C. Upper Extremity Impairments and Activities in Children with Bilateral Cerebral Palsy. Iran J Pediatr. 2017;27(6):e7711.
35. Tonak HA, Kilic MC. Serebral Palsili Çocuklarda Üst Ekstremite Fonksiyonelliğinin İncelenmesi. Aydın Sağlık Dergisi. 2016;2(2):37-50.