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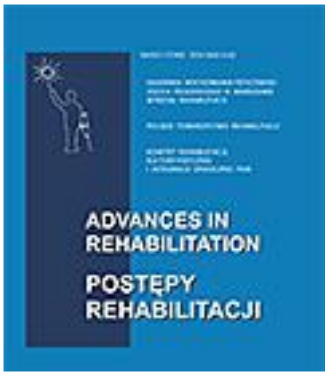

Original article

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Investigation of the Relationship Between Upper Extremity Lateralization and Dual Task Cost in Individuals with Hemiplegic Cerebral Palsy

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Abstract

Introduction: This study aims to investigate the relationship between upper extremity lateralization and dual-task cost in individuals with Hemiplegic Cerebral Palsy (HCP). This is a new and unknown issue in Cerebral Palsy.
Material and methods: The descriptive and cross-sectional study was conducted with 63 individuals with Hemiplegic Cerebral Palsy (n = 40) and typically developing peers (n = 23) between the ages of 7-17 years old. A pre-assessment was performed with the Gross Motor Function Classification System, Manual Ability Classification System, and Communication Function Classification System of the individuals with HCP. Left-right judgement was assessed by the laterality judgement task; manual ability was evaluated with the Nine Hole Peg Test (NHPT). While functional tests included upper extremity functional tests, and dual-task interferences of this test and the NHPT was also assessed.
Results: A significant difference was found between the HCP group and the typically developing group in lateralization accuracy and dual-task cost ($p < 0.05$). It was found that the relationship between lateralization response time and dominant cognitive NHPT dual-task cost ($r = 0.327$, $p = 0.040$). The relationship was found between lateralization accuracy and dominant cognitive NHPT dual-task cost, and lateralization response time and non-dominant motor NHPT dual-task cost ($r = -0.360$, $p = 0.023$; $r = 0.312$, $p = 0.050$, respectively).
Conclusions: Individuals with HCP have difficulty with dual tasks compared to typically developing peers. There is a relationship between upper extremity lateralization and dual-task cost in individuals with HCP. This can be a significant point for designing more effective intervention approaches on upper extremity lateralization and dual-task individuals with HCP.

Keywords: Cerebral palsy, Dual-task, Left-right judgement, Upper extremity

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Introduction

Cerebral Palsy (CP) refers to a motor disorder caused by brain damage that occurs congenitally or in the early postnatal period [1]. Individuals with CP have a lower functional capacity in one upper extremity compared to the other. This adversely affects daily living activities [2]. Several studies have already reported longer movement durations, reduced movement speed, smoothness, reaching, grasping, releasing and manipulating objects, which affects many activities of daily living in children with Hemiplegic Cerebral Palsy (HCP) compared to typically developing (TD) children [3,4].

In individuals with CP have upper extremity motor functional impairments, in addition to this, they also experience motor planning and lateralization deficits [5,6]. Lateralization involves the function of right-left discrimination to determine which side the limb belongs to. Right-left discrimination requires several cognitive skills, such as the integration of sensory and visual information. Furthermore, another function of the left-right discrimination is the visuospatial ability to mentally manipulate returned images or objects [7]. Lateralization abilities have often been assessed in children with CP and healthy children using a laterality judgement task [6,8,9].

This task involves the displayed pictures related to a extremity and requires the individual to make a laterality judgement [10]. In this task, individuals engage in a spatial orientation and mental problem-solving process to determine to make the laterality decision [11]. Lateralization is often used as a guide in assessment and rehabilitation studies of motor imagery skills in children with CP [12,13].

A small number of studies were conducted to test the laterality judgement task in CP [14-16]. However, the current evidence points to individuals with HCP being able to perform this judgement task, but it also indicates that these abilities are affected [6,12].

In daily life, we rarely perform one task at a time. Rather, our daily activities often involve performing two or more tasks at the same time, such as walking and walking and talking on the phone, or walking while looking for something in a pocket, known as dual-tasking [17]. Therefore, the evaluation of dual tasks in individuals with CP is an important aspect. In dual task assessment, an additional motor or cognitive task is given to the motor or cognitive performance performed by the individual. Dual-task ability refers to an individual's capacity to perform two tasks simultaneously [18]. These tasks could be either motor or cognitive. The central processing capacity should be shared between two concurrent tasks to perform more than one task at the same time [17]. A decline in the performance of one or both of the tasks is known as the dual-task cost [19]. Several studies have indicated dual-task interference in both TD and clinical populations [20,21]. Due to deficits in motor or cognitive processing, dual-task interference is increased in neurologic populations [22]. Children with CP commonly have executive function, visual-spatial, and attention deficits, as well as learning difficulties [23]. These impairments can lead to difficulties under dual-task conditions where cognitive and motor tasks are performed simultaneously [24]. Individuals with CP experience a decline in performance and face challenges during dual tasks compared to single tasks [22,25-27].

None of the studies to date have examined the relationship between lateralization and dual-tasking in individuals with HCP. Only one of the study investigated upper extremity dual-task paradigms in children with HCP [21]. Lateralization and dual tasking are related to similar cognitive processes. As mentioned above, investigation of upper extremity dual-task paradigms and lateralization is important specifically in individuals with CP before implementing training aimed at the affected lateralization and dual-task. The aim of this study was to investigate the relationship between upper extremity lateralization and dual-task cost in individuals with HCP. In addition, the same skills will be evaluated in TD peers, and the results will be compared with those of individuals with HCP. This study may reveal the complexity of the dynamic relationship between upper extremity lateralization and dual tasking in individuals with HCP, and thus, it is thought to be able to guide future research in this field.

Materials and methods

Participants

The study included, 63 individuals aged between 7 and 17, consisting of and diagnosed with HCP (n = 40) and TD (n = 23) peers. Individuals with HCP were included in the study if their families agreed to participate, they had MACS (Manual Ability Classification System) Levels I-II-III, GMFCS (Gross Motor Function Classification System) Levels I-II-III, and scored 24 or higher on the Mini-Mental State Examination for Children. Individuals with HCP were excluded from the study if they had complex and advanced medical problems other than CP, had undergone surgical intervention or Botulinum toxin application in the last six months, or had experienced a fracture in the upper extremity in the last six months. TD children were reached through the snowball sampling method. Children with HCP were reached through Special Education and Rehabilitation Centers.

Written informed consent forms were obtained from all individuals participating in the study. The study was approved by the XXXXX University Ethics Committee for Noninterventional Clinical Researches (Protocol Number: 2023/255). This study was conducted following the Principles of the Declaration of Helsinki.

Outcomes

The socio-demographic information form was used to note the children's age, gender, height, weight, hand preference, and the socio-demographic information of the children's parents.

The Gross Motor Function Classification System, Manual Ability Classification System, and Communication Function Classification System (CFCS) were used to classify the gross motor function levels, manual abilities, and communication skills, respectively, of the individuals with HCP included in the study [28,29]. GMFCS is a five-level classification system based on child-initiated movements with an emphasis on sitting, movement and mobility [28]. MACS is a five-level classification system designed to categorise how individuals with CP use their hands to handle objects in daily activities [28]. The CFCS classifies the daily communication performance of children with CP between levels I and V. Level I-II-III refers to effective communication skills [29]. In order to meet the motor requirements of the assessments conducted as part of the study, participants were required to have GMFCS and CFCS levels I-II-III.

The cognitive functions of the participants were evaluated with the Mini-Mental State Exam for Children (MMc), a multifunctional screening tool used to assess cognitive impairments in children with CP [30,31]. The test includes the areas of recording, recall, attention and calculation, temporal orientation, spatial orientation and language [31].

<u>Laterality judgement task</u>

To evaluate participants' lateralization, a laterality judgement task (the individual deciding to which side a extremity belongs) was used. The Recognise Hand program developed and designed by the NOI group was utilized to assess laterality (right-left discrimination) (http://www.noigroup.com/Recognise). The participants were asked to decide whether the hand images belonged to the right or left side presented with images of right and left hands from different angles on a phone screen, The evaluated participants were expected to press the right or left selection button on the screen to choose which side the hand belonged to. Two practice trials were allowed. After the trials, each participant confirmed verbally that they understood the task instructions. Participants were presented with a total of 10 images at 5-second intervals, in a comfortable sitting position, on the phone screen [6]. The correct answer percentages and reaction time calculated by the program were used in the assessment of this task. Reaction time are expressed in seconds and correct answers are expressed in percentages. It can be stated that as the seconds and percentage values increase, the sharpness of the right-left discrimination (lateralization) is better.

Nine Hole Peg test

Nine Hole Peg Test (NHPT) is a standardized assessment method frequently used to measure manual ability in individuals with CP [32]. In the test, the child was instructed to place 9 pegs, into the holes on a platform as quickly as possible with their dominant hand first and then remove them. The time from the "start" command to the removal of the last peg was recorded. The same procedure was repeated with the non-dominant hand, so both extremities were evaluated. The participants were familiarized with one practice trial of the test. NHPT was carried out according to the original instructions established [32]. The intra-rater reliability coefficient was observed for the dominant side (ICC = 0.94) and the non-dominant side (ICC = 0.96) [32]. In the reference study, the mean ± SD for the dominant upper extremity was 29.06 ± 7.58 and 146.43 ± 93.63 for the non-dominant upper extremity [32].

Upper Extremity Functional Assessment

In the upper extremity functional assessment, the participant was asked to place their hand on a table at elbow height while in a sitting position. They were instructed to perform 20 consecutive repetitions of moving their hand to their mouth and then back to the table. The time taken to complete this task was recorded in seconds using a stopwatch. The dominant extremity was evaluated first, followed by the non-dominant extremity. The Intraclass Correlation Coefficient was 0.99 for upper extremity functional test [33].

Dual-Task Paradigm

Participants were given dual tasks during the NHPT and upper extremity functional assessments to evaluate dual-task interference. For the cognitive task during the NHPT, participants were asked to count backward by one. For the motor task during the NHPT, participants were instructed to alternately perform elbow flexion-extension movements with the opposite arm. While performing the upper extremity functional assessment, as a cognitive task, participants were asked to list animal names simultaneously. As a motor task, they were instructed to alternately perform supination-pronation movements with the opposite extremity. During the evaluations, the time was recorded in seconds using a stopwatch. In the dual-task interference assessment, participants were instructed to perform both tasks without prioritizing one over the other and to do their best. They were also told not to pause for thought. The complexity of the upper extremity functions under dual-task conditions was measured by calculating the 'dual-task cost' for both tasks. The formula used to calculate the dual-task cost is according to the original instructions indicated [20].

Statistical analysis

G*Power application was used for post-hoc power analysis. A significance level of 5% and a power (1-b) of 80% were assumed, and a medium effect size (d = 0.517) in the population was assumed. The sample size was calculated to be 32 individuals [11]. Statistical analyses were conducted using the SPSS 25 (Version 25, Chicago, USA) software package. The normality of the data was analytically examined using the Kolmogorov-Smirnov Test. Descriptive analyses for numerical measurements were expressed in terms of arithmetic mean and standard deviation (Mean ± SD). An Independent Sample t-test was used for comparison between groups' lateralization values and dual-task cost. The relationship between lateralization and dual-task cost was examined using Pearson correlation analysis.

Results

In this study, 40 children with HCP between the ages of 7-17, with a mean age of 12.47 ± 3.32, additionally, 23 TD children with a mean age of 12.0 ± 2.81 years were included. The demographic characteristics of the children are presented in Table 1.

Tab. 1. The physical and sociodemographic characteristics

		Hemiplegic Cerebral Palsy	Typically Developing
		Mean ± SD	Mean ± SD
Age		12.47 ± 3.32	12.0 ± 2.81
BMI (kg/m2)		18.57 ± 3.07	16.16 ± 2.18
Duration of physiotherapy (years)		7.7 ± 3.6	
MMC (0-37)		29.17 ± 1.81	29.95 ± 0.92
		n (%)	n (%)
Gender	Male	23 (57.5)	11 (47.8)
	Female	17 (42.5)	12 (52.2)

Dominant hand	Right Left	14 (35.0) 26 (65.0)	17 (73.9) 6 (26.1)
GMFCS Level	Level I Level II Level III	20 (50.0) 17 (42.5) 3 (7.5)	
MACS Level	Level I Level II Level III	15 (37.5) 24 (60.0) 1 (2.5)	
CFCS Level	Level I Level II	22 (55.0) 18 (45.0)	
Educational Level of the Children	Primary Secondary School High School	19 (47.5) 16 (40.0) 5 (12.5)	5 (21.7) 15 (65.2) 3 (13.1)

BMI- Body Mass Index, CFCS- Communication Function Classification System, GMFCS- Gross Motor Function Classification System , MACS- Manual Ability Classification System, MMC- Mini-Mental State Exam for Children, SD- Standard Deviation

The comparison of lateralization and dual-task between groups is presented in Table 2. Except for lateralization accuracy and dominant cognitive NHPT dual-task cost, a significant difference was found between the HCP group and the TD group in all parameters ($p < 0.05$).

Tab. 2. Comparison of lateralization and dual-task between groups

	Hemiplegic Cerebral Palsy Mean ± SD	Typically Developing Mean ± SD	t	p
Lateralization accuracy (%)	46.37 ± 18.43	53.69 ± 16.04	1.589	0.117
Lateralization response time (seconds)	2.42 ± 0.45	1.74 ± 0.31	6.973	0.000*
Non-dominant cognitive functional dual-task cost	32.95 ± 40.93	4.19 ± 3.00	4.423	0.000*
Non-dominant motor functional dual-task cost	38.57 ± 42.48	6.29 ± 5.65	4.733	0.000*
Dominant cognitive functional dual-task cost	39.39 ± 43.12	9.31 ± 8.02	4.284	0.000*
Dominant motor functional dual-task cost	37.69 ± 38.21	10.00 ± 7.94	4.420	0.000*
Dominant cognitive	12.32 ± 15.29	9.39 ± 4.69	1.124	0.266

NHPT dual-task cost				
Non-dominant cognitive NHPT dual-task cost	9.72 ± 9.38	5.13 ± 3.10	2.836	0.006*
Dominant motor NHPT dual-task cost	20.42 ± 13.65	10.00 ± 9.17	3.615	0.001*
Non-dominant motor NHPT dual-task cost	19.65 ± 13.29	7.78 ± 9.73	4.061	0.000*

NHPT- Nine Hole Peg Test, SD- Standard Deviation, t- Independent Sample t-test Coefficient, p- p value, *p < 0.05

The results of the Pearson correlation analysis performed to determine the relationship between lateralization and dual-task in individuals with HCP are presented in Table 3. A relationship was found between lateralization accuracy and dominant cognitive NHPT dual-task cost. It was determined that the relationship between lateralization response time and dominant cognitive NHPT dual-task cost, lateralization response time and non-dominant motor NHPT dual-task cost ($p < 0.05$, Table 3).

Tab. 3. The relationship between lateralization and dual-task in individuals with HCP

	Non-dominant cognitive functional dual-task cost	Non-dominant motor functional dual-task cost	Dominant cognitive functional dual-task cost	Dominant motor functional dual-task cost	Dominant cognitive NHPT dual-task cost	Non-dominant cognitive NHPT dual-task cost	Dominant motor NHPT dual-task cost	Non-dominant motor NHPT dual-task cost
Lateralization accuracy	r = -0.204 p = 0.208	r = -0.185 p = 0.253	r = -0.134 p = 0.409	r = -0.048 p = 0.767	r = -0.360 p = 0.023*	r = 0.036 p = 0.828	r = 0.147 p = 0.366	r = 0.184 p = 0.256
Lateralization response time	r = 0.230 p = 0.154	r = 0.306 p = 0.555	r = 0.192 p = 0.235	r = 0.100 p = 0.539	r = 0.327 p = 0.040*	r = 0.100 p = 0.538	r = 0.187 p = 0.248	r = 0.312 p = 0.050*

NHPT- Nine Hole Peg Test, r- Pearson correlation analysis, p- p value, *p < 0.05

Discussion

This study investigated the relationship between upper extremity lateralization and dual-task cost in individuals with HCP. The results revealed that the response times of HCP to hand lateralization were slower than the TD peers, and dual tasks were higher to complete. In addition, a relationship was found between lateralization and NHPT dual-task cost for certain assessment parameters.

By previous studies, our results, indicate that the hemiplegic groups showed no difference in the accuracy of left-right judgements compared to their TD peers [10,16]. We determined that the accuracy was similar to that of TD peers. Although the accuracy in the HCP group was similar, the response times were significantly slower. These findings relating to accuracy in the hand laterality judgement task are particularly important because percentages of incorrect decisions are likely to mean greater deficits than slow but accurate performances. This indicates that individuals with HCP perform accurately at rates close to TD controls, but they take higher to decide when giving the correct responses. This can be explained by an increase in spatial orientation processes characterized by impairments in the mental representation of the hand associated with upper extremity motor losses.

Neuroimaging studies have indicated that during the process of making a laterality judgement, individuals visualize their own hands in the position of the hand they see on the screen [11,34]. The common limitations highlighted by the researchers were related to the inherent discrepancies between groups and the level of cognitive demand, unrevised to the basic task abilities of the participants [27]. It is evident that both the laterality judgement task process and the dual-task paradigm inherently involve mental processes. In a study examining dual-task interference in groups with neurological disorders, it has been reported that there is a decrease in the speed of movement during dual-task performances compared to single tasks, with the most significant decrease observed in children with CP [22]. This indicates that individuals with CP experience greater challenges in dual tasks compared to other groups with neurological impairments.

Only a few studies have investigated dual-task interferences in children with CP. The experimental paradigms used in these studies have preliminary centering on the effects of dual tasks on time-distance characteristics of walking, balance, and postural stability [22,27,35,36]. Consequently they observed that during dual motor tasks, there was a decrease in walking speed, width, and length of stride compared to single motor tasks. In addition, it showed an increase of body sway in children with CP during a dual-task in standing, greater than in TD children [37].

In individuals with CP, the loss of upper extremity motor control results in restrictions in daily life activities and is known to limit the child's participation in personal care, social, and environmental roles [21,38]. Accordingly, it can be stated that research on dual tasks in the HCP population should not be limited to the lower extremity, and the upper extremity paradigm should also be investigated more comprehensively. It is recommended that conventional physiotherapy programs for individuals with HCP be supplemented with upper extremity dual-task training and left-right judgements, and their effects be investigated.

In the only study investigating the upper extremity dual-task paradigm in CP, it was found that individuals with HCP had higher dual-task conditions and dual-task cost compared to their typically developing peers, and there was increased activation of the prefrontal cortex [21]. In this study, it was found that the dual-task cost evaluations of individuals with HCP were higher compared to the typically developing peers. All these findings indicate that individuals with HCP experience losses in their current functional capacity during complex tasks in daily life. It can also be stated that the additional tasks given during upper extremity motor performances are more challenging for individuals with HCP.

It has been indicated that laterality judgement tasks are affected in individuals with CP [5,6,12,15,16] and the challenges of dual tasks [22,25-27,37] have been separately specified. However, none of the studies conducted to date have investigated the relationship between upper extremity lateralization and dual-task cost in children with CP being jointly assessed and specified.

In this study, a relationship was found between lateralization accuracy and dominant cognitive NHPT dual-task cost, lateralization response time, and non-dominant motor NHPT dual-task cost. Even though they might be seen as independent evaluations, these findings suggest a dynamic relationship between laterality judgement tasks and dual-task cost. In conclusion, it can be stated that improving one of these two factors might have positive effects on the other. However, this situation needs to be supported by clearer evidence from future studies. In forthcoming research, it is recommended that dual-task and accuracy of left-right judgements in individuals with CP be considered; and investigated jointly. Investigation of upper extremity lateralization and dual-task performances is essential specifically in children with HCP because upper extremity lateralization and dual-task refer to similar cognitive processes.

One of the strengths of this study is that it is the first to investigate upper extremity dual-task in conjunction with lateralization in individuals with HCP. Another one is that we compared the results with a typically developing control group. The study sample has a wide age range the main limitation of this study. The study findings reflect only the results of children with HCP. Therefore, the conclusions should not be generalized to other types of CP without further investigation. Enhancing control of the affected upper extremity performance may potentially contribute to the reduced upper extremity dual-task performance. The relationship between lateralization, dual-task, and upper extremity skills should be considered in the design of rehabilitation protocols.

Interferences between motor and cognitive tasks have significant effects on upper extremity performance in children with TD and HCP. In conclusion, our study highlights and clarifies the complex relationship between upper extremity lateralization and dual-task in individuals with HCP. This can be a significant point for designing more effective intervention approaches on this subject. It can be emphasized that for physiotherapists and clinicians working in the field, the evaluation of upper extremity lateralization and dual-task should be included and researched in assessment and intervention approaches.

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Conflicts of interest

The authors declare no conflicts of interest.

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