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Efficacy of dual task training for children with cerebral palsy: a randomized controlled trial

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(Short title) Dual task training in children with cerebral palsy

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Efficacy of dual task training for children with cerebral palsy: a randomized controlled trial

Abstract

Background: This study aims to compare the effects of Dual Task (DT) training on walking, balance, and participation parameters in children with Cerebral Palsy (CP) with those of Single Task (ST) training.

Methods: The Edinburgh Visual Gait Score (EVGS), the Timed Up and Go (TuG), the 10-m walk test, the Pediatric Balance Scale (PBS), and the Pediatric Outcome Data Collection Instrument (PODCI) were administered before and after treatment. Participants in both groups received treatment twice weekly for 6 weeks (45 minutes per session). The control group received ST training, while the study group performed the same activities combined with age-appropriate cognitive tasks (DT training).

Results: After adjusting for baseline scores using ANCOVA, significant differences were found between the study and control groups in the DT conditions of the 10-m walk test ($F = 5.297$, $p = 0.031$, $\eta^2 = 0.194$) and the TuG test ($F = 7.975$, $p = 0.010$, $\eta^2 = 0.266$), both indicating large effect sizes. No significant differences were observed between the groups for the ST 10-m walk test ($F = 1.771$, $p = 0.197$, $\eta^2 = 0.075$) or for the EVGS, PBS, and PODCI outcomes after controlling for baseline scores.

Conclusions: DT training may have positive effects on walking and functional activities of children with CP. The addition of balance and mobility exercises, including DT, to rehabilitation programs for children with CP may improve their success with DT, which is frequently encountered in daily life.

Trial registration: Clinicaltrials.gov Registry: NCT04777773

Keywords: Cerebral Palsy; Child Disability; Adolescence; Exercise; Participation; Physical Disabilities; Dual-Task.

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1. Background

Cerebral Palsy (CP) is a group of movement and posture disorders that cause limitations in activity and are linked to permanent, non-progressive injury of the developing fetal or infant brain. In addition to motor disorders in CP, it may be accompanied by sensory, perception, cognitive, communication, and behavioral disorders, epilepsy, and secondary musculoskeletal problems [1,2]. From the perspective of the International Classification of Functioning, Disability and Health (ICF), created by the World Health Organization with the aim of classifying health and health-related situations, body structures (e.g., extremities), body functions (e.g., mental functions), activities (e.g., walking) and participation (e.g., playing sport) may be affected among factors that constitute the functionality of individuals with CP. In this situation, the person may be disabled, along with experiencing functional disorder, activity limitation, and participation restrictions [3]. From the ICF perspective, the importance of interventions for CP that optimize quality of life, activity, and participation, rather than focusing on body structure and function, emerges [4].

Dual Task (DT) refers to situations in which postural control is performed alongside a secondary task [5]. According to the DT paradigm, DT performance is affected by many factors related to the task, environment, and individual. Extrinsic factors affecting DT performance include factors linked to the nature of the primary task, the nature of the secondary task, and environmental conditions. Intrinsic factors affecting DT performance relate to the individual [6,7]. In DT situations where the attentional demands of postural and cognitive tasks exceed available attentional resources, delays or disruptions may occur in one or both tasks. This situation is called dual task interference (DTI). The amount of DTI is linked to the automaticity of motor tasks. If motor learning is complete and the motor task is automatic, sufficient attention can be devoted to the cognitive task, thereby decreasing the amount of DTI [8]. In children, causes of DTI are the still-developing neurological system, high cognitive skills, and capacity

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of attentional resources [9]. In children with spastic CP, involvement of attentional division centers in the brain may be observed, driven by white matter disorders along pathways that connect the prefrontal cortex to other brain structures [10]. Additionally, motor movements in DT conditions are known to emerge from interactions between cognitive, mechanical, perceptual, and neurological mechanisms. In neuromotor disorders such as CP, any disruption of central coordination processes involving these mechanisms will inevitably lead to DTI [11]. It was clearly shown that children with CP have more DTI compared to their typically-developing peers [10, 12, 13]. However, randomized controlled studies investigating the effects of an exercise program that includes DT on walking, balance, and participation parameters in children with CP are lacking in the literature. This study was planned based on this deficiency in the literature. The aim of this study was to examine the effects of DT training on walking and balance parameters with participation in children with CP. Additionally, the aim was to compare DT training with Single Task (ST) training.

2. Methods

Study Design and Setting

This prospective randomized controlled study was approved by the Ordu University Clinical Research Ethics Committee (2019-103) and registered at ClinicalTrials.gov (NCT04777773). The study was conducted at Ordu University, where the corresponding author was affiliated; therefore, ethical approval was obtained from the same Institutional Review Board. This research was conducted within the scope of a doctoral thesis in accordance with the principles of the Declaration of Helsinki. The G-Power 3.1.9.4 analysis program was used to calculate the sample size. The sample size was calculated using similar studies on the topic as references [14]. In the reference study, the effect size was calculated as 1.41 based on mean scores for the 10-meter walk test. Based on this effect size with 5% error (α) and 90% (1-β) power, the study sample comprised a total of 24 children, with 12 in the study group and 12 in the control group.

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A total of 29 children were included to account for possible data loss during the study. Pre-treatment assessments were completed for 29 children with CP. Of the 29 children with initial assessment, 1 decided not to participate in the study and left. During the 6-week treatment program, which began with 28 children, 2 children missed 3 consecutive physiotherapy sessions, and 1 child moved to another town; these children were removed from the study. The study included post-treatment assessments of 25 children with CP: 13 in the study group and 12 in the control group. The study was conducted and reported in accordance with the CONSORT (Consolidated Standards of Reporting Trials) guidelines, and a CONSORT flow diagram was used to illustrate participant enrollment, allocation, follow-up, and analysis (Figure 1).

Participants

This study was conducted with children with CP attending physiotherapy programs in Ordu and Giresun provinces, who provided voluntary consent forms from themselves and their parents, agreeing to participate in the study.

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Inclusion criteria: Children with spastic type unilateral and bilateral involvement, aged 7-18 years, Gross Motor Function Classification System (GMFCS) I and II, attending normal education, with no surgical operations involving the musculoskeletal system in the last 6 months, and no botulinum toxin administration in the last 6 months.

Exclusion criteria: Children who could not complete the cognitive task (counting backwards beginning at a number between 0 and 100) or who had behavior problems, making participation in the study difficult.

Data Collection and Outcome Measures

Participants were randomly assigned to the study and control groups using unstratified simple randomization in a 1:1 allocation ratio. The randomization sequence was generated and

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implemented by an independent researcher who was not involved in participant assessment or treatment to minimize allocation bias. Before and after treatment, assessments were conducted by the same assessor (a specialist physiotherapist with 9 years of experience in the field of CP).

GMFCS, Manual Ability Classification System (MACS), and Communication Function Classification System (CFCS) were used to determine the functional levels of children.

The Edinburgh Visual Gait Score (EVGS) was used to assess the gait. EVGS was developed to create an easy-to-use walking score compatible with 3-dimensional walking analyses in children with CP [15]. The EVGS is a valid and reliable method for application to children with CP [15, 16]. The intra-rater and inter-rater reliability of the EVGS is sufficient for observational gait assessment [17]. In this study, camera recordings were conducted in a walking area measuring 10 m by 2 m. Clothing was selected to facilitate observation of the trunk, pelvis, and extremities. During EVGS evaluations, shoes were worn as necessary, although orthotics were not employed. Walking analysis recordings were performed in ST and DT conditions at the speed chosen by the child. Videos recorded from anterior, posterior, right lateral, and left lateral were stopped when necessary, and range of motion angles were measured and scored. For total scores, the points for right and left extremities were added.

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The Timed Up and Go (TuG), 10 m walking test, and Pediatric Balance Scale (PBS) were administered to assess walking and balance. Health-related quality of life was assessed with the Pediatric Outcome Data Collection Instrument (PODCI).

The TuG test was performed with children sitting on chairs with knee and hip angles set to 90 degrees. Children with their feet fully touching the ground stood up from the chair and walked 3 m while wearing shoes and supports, such as an Ankle-Foot Orthosis (AFO), used in daily life. At the marked location, 3 m away, they turned, returned to the chair, and sat down

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again. The chronometer started when the 'go' command was given and stopped when the children sat with their backs to the chair backs [18].

The 10 m walking test was performed on a walking track marked for acceleration and slowing (2 m from the start and 2 m from the end). The duration to walk the remaining 6 m distance was measured with a chronometer [19].

PBS was also performed. The PBS is a version of the Berg Balance Scale modified for children. The PBS was adapted for school-age children with mild-to-moderate motor disorders [20].

PODCI was developed by a workgroup assembled by the Pediatric Orthopedic Society of North America. The Turkish version of PODCI is a valid and reliable instrument for assessing the health-related quality of life in individuals with CP. Caregivers filled out the PODCI forms before and after treatment. Standardized scores between 0 and 100 are obtained using the scoring table [21].

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Treatment

Participants in both groups received a structured treatment program conducted 2 days per week for 6 weeks, with each session lasting approximately 45 minutes.

Treatment program in study and control groups:

- Stretching of lower extremity flexor muscle in supine position (30 s x 10 repeats x 3 sets), stretching of lower extremity adductor muscles in supine position (30 s x 10 repeats x 3 sets), strengthening of lower extremity extensor muscles in prone position (10 s x 10 repeats x 3 sets), strengthening of lower extremity abductor muscles in side position (10 s x 10 repeats x 3 sets), strengthening of trunk extensor muscles in prone position (10 s x 10 repeats x 3 sets), strengthening of abdominal muscles in supine position (10 s x 10 repeats x 3 sets).

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Then a 15-minute program for balance and mobility

- Balance on a single foot, walking forward, backwards, and sideways on a hard surface, walking forward, backwards, and sideways on a soft surface (5 min)
- Walking while picking up an object from the ground, walking while passing over obstacles (5 min)
- Crawling position, balance on knees and half-knee position, throwing and catching a ball while standing, walking up and down stairs (5 min).

1. **Control Group Conventional Physiotherapy Program**

The treatment program in the control group consisted of lower-extremity and trunk stretching and strengthening exercises, implemented during the first 30 min of the physiotherapy program. Then, balance, walking, and stair activities were performed for 15 min in the physiotherapy program.

2. **Study Group Dual-Task Physiotherapy Program**

The treatment program in the study group consisted of lower-extremity and trunk stretching and strengthening exercises, implemented during the first 30 min of the physiotherapy program. Then, balance, walking, and stair activities were performed as part of a 15-min physiotherapy program. In the study group, balance, walking, and stair activities were performed with age- and cognitive-level-appropriate tasks (Figure 1). Cognitive tasks included the following;

- Rhythmic counting forward and backward (counting backward and forward in twos, threes, sevens),
- Listing objects and names beginning with a certain letter (e.g., names beginning with "M"),
- Listing numbers, days, and months backwards,
- Identifying sounds heard (easily understood sounds like a cat meowing, a door closing, a bird chirping),

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- Remembering and repeating 5 names,
- Listing relatives and their names,
- Listing animal and fruit names.

Analysis of data

Data obtained in the research were analyzed using IBM SPSS Statistics version 23. When analyzing study data, descriptive statistical methods (mean, standard deviation, frequency, percentage) were used. To compare quantitative data, the normality of the distribution was assessed using skewness and kurtosis. If skewness and kurtosis values fall between -2 and +2, the data are considered normally distributed [22]. The research used parametric tests for data that were normally distributed.

Within the experimental design framework, Analysis of Covariance (ANCOVA) was used to control for baseline differences when comparing post-test scores between groups. In the ANCOVA model, post-test scores were treated as the dependent variable, group as the independent variable, and the corresponding pre-test scores as covariates. This approach allowed the evaluation of group differences in post-test scores while controlling for baseline levels. The level of statistical significance was set at $p < 0.05$ for all analyses. When a significant difference was detected, the effect size was calculated. In the ANCOVA analyses, effect size was reported as partial eta-squared (η^2). According to Cohen's [23] recommendations, values of 0.01, 0.06, and 0.14 were interpreted as small, medium, and large effect sizes, respectively. Partial eta-squared indicates the proportion of variance in the dependent variable explained by the independent variable after controlling for the covariates.

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3. Results

Baseline demographic and clinical characteristics were comparable between the groups. Overall, the groups were comparable in terms of sex, orthotic device use, GMFCS, CFCS, MACS levels, gestational age, height, and weight (Table 1).

Individual pre– and post–trajectories are illustrated in a spaghetti plot, with group mean ± 95% confidence intervals, in Figure 2.

The ANCOVA results indicated that, after controlling for baseline scores, there was no statistically significant difference between the study and control groups in the adjusted post-test scores for the 10-m walk ST test ($F = 1.771$, $p = 0.197$, $\eta^2 = 0.075$). In contrast, a significant difference was found in the 10-m walk DT test ($F = 5.297$, $p = 0.031$, $\eta^2 = 0.194$), with the study group showing a significantly lower adjusted post-test mean than the control group. The effect size for this difference was large.

For the EVGS, no significant differences were observed between the groups after controlling for baseline scores in either the ST ($F = 2.574$, $p = 0.123$, $\eta^2 = 0.105$) or DT ($F = 0.586$, $p = 0.452$, $\eta^2 = 0.026$) conditions (Table 2).

Table 3 presents the post-test scores for the study and control groups on the TuG, PBS, and PODCI, analyzed using ANCOVA with pre-test scores as covariates. After adjusting for baseline scores, no significant difference was found between the groups in the TuG (ST) test ($F = 4.175$, $p = 0.053$, $\eta^2 = 0.159$). In contrast, for the TuG (DT) test, the study group had a significantly lower adjusted post-test mean than the control group ($F = 7.975$, $p = 0.010$, $\eta^2 = 0.266$), indicating a large effect size.

For the PBS and PODCI tests, no significant differences were observed between the groups after controlling for baseline scores (PBS: $F = 0.735$, $p = 0.400$, $\eta^2 = 0.032$; PODCI: $F = 0.000$, $p = 1.000$, $\eta^2 = 0.000$).

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4. Discussion

In this study, the efficacy of a conventional physiotherapy program that included DT was evaluated in children with CP. Results revealed that the exercise program, including DT, was effective in improving walking and balance parameters completed under DT conditions within a short 6-week duration. When the exercise program, including DT, was compared with the conventional physiotherapy program (ST), improvements were observed in walking and balance parameters with DT. This situation shows that adding balance and mobility exercises, including DT, to rehabilitation programs for children with CP may improve their performance on DT tasks commonly encountered in daily life.

Studies investigating the lifelong variation in DT performance showed that pediatric and elderly groups displayed low postural performance under DT conditions. DTI formed a U-shaped graph over a lifetime [24]. The literature demonstrates that DT skills begin to develop at 4-6 years of age, and continue to develop from 7 years of age until adulthood. Therefore, it is more appropriate to conduct DT assessments after the age of 7 [25]. In studies assessing walking as the motor task in motor-cognitive DT, DTI generally declines with age in pediatric groups. However, a few studies showed that DTI did not change or increased with age [24, 26, 27]. In light of this information, our study included children aged 7 to 18 years. It is clear that DT training for individuals with CP aged 18 and over is a separate area of study.

In the literature, the duration of DT treatment programs varies. Just as there are studies assessing treatment efficacy after a single session of DT training, there are studies researching the efficacy of 2-12-week exercise programs [28-31]. There is no consensus about treatment intensity, but generally, 30-60 minutes of DT exercises are performed in 2 or 3 sessions per week. A meta-analysis found no correlation between treatment duration and efficacy in cognitive interventions [32]. In fact, another study reported that a longer treatment duration may reduce treatment efficacy due to cognitive fatigue [33]. Studies performed with children

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and young people with CP appear to apply 6-8-week programs with 2-3 sessions per week. In this study, the treatment program was implemented as 2 sessions, each lasting 45 minutes, over 6 weeks for both the study and control groups. In the literature, DT treatment was implemented as home programs [34], group exercises, or treadmill-based sessions [31]. In this study, individualized treatment programs were implemented for the study and control groups. Motor-cognitive DT situations challenge individuals with CP more than motor-motor tasks [35]. As a result, motor-cognitive DT training was implemented in this study.

Studies researching the difference between ST and DT conditions identified DTI in children, in adults, and in groups with neurological involvement. There are studies researching the efficacy of DT training for Parkinson patients, elderly individuals, elderly individuals with osteoporosis, patients with spinal cord injuries, patients with multiple sclerosis (MS), stroke patients, transfemoral amputees, individuals with dementia, and Alzheimer patients [36]. However, there is a notable paucity of studies evaluating the efficacy of exercise programs integrating DT in pediatric populations. A study of typically developing adolescents found that DT implementations provided better cognitive performance and postural control. Furthermore, difficult cognitive tasks developed balance parameters better than easy cognitive tasks [28]. Another adolescent study found that DTI decreased during walking, regardless of the DT/ST training group [37]. Studies of children with neurological involvement are very limited. The reason for this may be the direct impact of the site and extent of neurological involvement on DT skills, which have a one-to-one relationship with the development of the dorsolateral prefrontal cortex. In this situation, homogeneity among the study groups may pose a challenge to the research [38]. There are very few studies about children with CP. According to a study of children with CP, adding DT exercises to physiotherapy programs may improve the development of postural control [39]. Another publication presented a 15-year-old spastic triplegic case. According to the study's results, DT exercises performed using a task-oriented

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approach were found to improve dynamic balance and functional mobility. As this case study provides a comprehensive assessment and an example of a treatment program, it contributes to the literature. However, it is difficult to determine the source of the positive outcomes after treatment, as the study included different applications such as treadmill use, yoga, and home programs [40]. A study of children with spastic diparetic CP identified that static and dynamic sitting balance were developed in the DT and ST groups. Additionally, this study emphasized the superiority of DT exercises compared to ST exercises [41]. A published pilot study combined DT exercises with direct current stimulation. According to this research, DT training during anodal direct current stimulation applied to the motor control area of the brain in children with CP resulted in increased functional mobility [29]. Unlike the literature, our study evaluated DT tests before and after treatment. After DT exercises, children with CP were found to have improvements in DT walking and balance parameters. This suggests that walking and functional mobility under DT conditions were more automatic in the study group after treatment.

It is important to identify the participation effect of treatment within the scope of ICF [4]. With this aim, we assessed the participation effect of the physiotherapy program in the study and control groups. However, no difference in participation levels was identified between the study and control groups after treatment. During participation assessments, assessment differences may occur for individuals with CP from the family perspective [42]. In this study, the participation assessment was performed by caregivers. There is a need for studies that use self-assessments from individuals with CP to evaluate the effect of treatment on participation. However, it should not be forgotten that psychosocial, emotional, individual, and environmental factors may affect participation. In addition to these, it should be noted that the physiotherapy program in this study may remain inadequate for achieving multidimensional rehabilitation outcomes. There is a need for multidimensional biopsychosocial studies targeting the

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participation of children with CP. Additionally, the fact that the sub-dimensions of participation were not examined, or that a participation evaluation could be performed to reveal changes more sensitively, is a limitation of our study. In the literature, a study stated that DT training may increase health-related quality of life [43]. The study duration suggests that extending the 3 months may affect quality of life. Additionally, in their study, significant increases across all assessment parameters may have contributed to improved quality of life. These results lead to consideration of the need for a longer duration program in our study, which is a limitation.

In the literature, studies have reported significant increases in postural stability and in static and dynamic sitting balance after DT treatment in children with CP [39, 41, 44]. In our study, no differences in postural stability after treatment were identified between the study and control groups. This result suggests the need for studies assessing DT treatment using more sensitive and objective methods.

In terms of time-distance parameters, addition of DT during walking can be summarized as reduced walking speed, cadence, and step length, and increased step duration and step duration variability [45]. Some studies performed with children with CP researched these parameters using high-technology walking assessment equipment [12, 35]. However, in our study, only walking speed could be assessed among these parameters, which is a limitation. There is a need for advanced studies that assess other time-distance features affecting walking to reveal treatment efficacy. Another limitation of the study is that DT training in the study group lasted only 15 minutes per session. The short duration of DT treatment in this way was limited by the 45-minute session length at our organization. Additionally, this duration included 30 minutes of stretching and strengthening.

This study has several strengths, including its randomized controlled design and the use of baseline-adjusted statistical analyses. The findings of this study suggest that DT training may offer specific benefits in improving DT walking performance and DT functional mobility in

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children with CP. While no significant differences were observed in ST walking, gait quality, balance, or participation outcomes, the improvements observed in DT performance highlight the potential value of incorporating cognitively challenging activities into rehabilitation programs. Future research should, based on objective data, examine in more detail the optimal intensity and long-term effects of DT interventions in this population to maximize functional outcomes.

5. Conclusion

In conclusion, DT training may positively affect walking and functional activities in children with CP. The incorporation of cognitive tasks during balance and mobility activities may serve as a practical therapeutic approach for children with cerebral palsy, facilitating their ability to cope with DT situations encountered in daily life.

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Abbreviations

DT	Dual Task
CP	Cerebral Palsy
ST	Single Task
DTI	Dual Task Interference
EVGS	Edinburgh Visual Gait Score
TuG	Timed Up and Go
PBS	Pediatric Balance Scale
PODCI	Pediatric Outcome Data Collection Instrument
ICF	International Classification of Functioning, Disability and Health
GMFCS	Gross Motor Function Classification System
AFO	Ankle-foot Orthosis

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Author contributions

SBO: Design the study, theoretical framework, data collection, performed the procedure, discuss the findings, and draft manuscript. BE: Design the study, theoretical framework, analyzed the data, and study supervision. All authors reviewed the final manuscript. The authors read and approved the final manuscript.

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Data availability

The data are available from the corresponding author upon request.

Declarations

Ethics approval and consent to participate

This study was approved by the Ordu University Clinical Research Ethics Committee (2019-103) and registered at ClinicalTrials.gov (NCT04777773).

Written informed consent was obtained from the parents of each child.

Consent for publication

Not Applicable.

Competing interests

The authors declare no competing interests.

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