Comparative Effects of Motor and Cognitive Dual Task Gait Training on Balance, Spasticity and Quality of life in Patients with Diplegic Cerebral Palsy

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Abstract

Background: Cerebral palsy (CP) is a neurodevelopmental disorder affecting motor skills and muscle tone, often associated with concurrent cognitive impairments. A growing body of evidence supports implementing dual-task gait training for enhancing functional mobility and cognitive performance. However, its impact on children with diplegic cerebral palsy remains under-researched. This study aimed to compare the effects of motor and cognitive dual-task gait training versus conventional therapy on balance, spasticity, and quality of life in children with diplegic cerebral palsy. A total of 52 participants, aged 6-12 years with diplegic CP, were randomized into two groups. Group 1 received conventional therapy (n=26), and Group 2 received motor and cognitive dual-task gait training (n=26). The interventions were conducted over eight weeks. Assessments, including the Gait Profile Score (GPS), Pediatric Berg Balance Scale (PBS), Gross Motor Function Classification System (GMFCS), and Cerebral Palsy Quality of Life (CP-QOL) were conducted at baseline, Week 4, and Week 8. The Dual-Task Gait Training Group demonstrated significant improvements in the GPS, PBS, GMFCS, and CP-QOL scores at Week 8 compared to the Conventional Therapy Group. Expressly, significant differences were noted in balance (PBS:

p<0.001), spasticity (GPS: p<0.001), gross motor function (GMFCS: p<0.001), and quality of life (CP-QOL: p<0.001). **Conclusion**: The findings suggest that motor and cognitive dual-task gait training could be more effective than conventional therapy for improving balance, reducing spasticity, and enhancing the quality of life in children with diplegic cerebral palsy.

Keywords: Diplegic Cerebral Palsy; Dual-Task Gait Training; Conventional Therapy; Quality of Life; Balance

INTRODUCTION

Cerebral Palsy (CP) is a complex group of permanent movement disorders arising from abnormal brain development or damage during childhood. It's multifaceted, with a spectrum that ranges from movement difficulties to cognitive impairments. Approximately 80% of CP cases are characterized as Spastic Cerebral Palsy, leading to increased muscle stiffness. Notably, 1 in every 323 children in the U.S. is affected by CP, with varying degrees of motor cortex and balance area impairments (Dan, 2022).

Ataxic Cerebral Palsy, affecting 1-10% of cases, is caused by cerebellum damage, crucial for fine motor control, balance, and coordination. Symptoms include difficulty with fine motor tasks, poor balance, depth perception issues, and challenges with rapid movements. The central impediment in ataxic CP is the lack of coordination, which often leads to falls. A comprehensive, multidisciplinary approach to rehabilitation is essential, encompassing physical, occupational, speech and language therapies, and assistive technology (Friedman et al., 2022). The cognitive aspect of CP also cannot be overlooked. Memory, attention, spatial cognition, and executive functioning can be impacted. Roughly 30-50% of children with CP exhibit cognitive impairments, affecting daily life and educational outcomes. Therapeutic interventions, combining cognitive and physical strategies, are vital for a holistic treatment approach (Hirides et al., 2023).

Gait problems and sensory deficiencies are among the significant physical concerns. Walking difficulties are characteristic, with types like spastic, ataxic, and dyskinetic gaits indicating the CP form. Solutions include gait training, orthotics, and in severe cases, surgical intervention (Hodgson et al., 2023). Sensory challenges,

ranging from vision and hearing loss to altered touch sensitivity, further highlight CP's complexity, necessitating therapies like glasses or hearing aids (Hodgson et al., 2023).

Early diagnosis of CP in children is crucial for effective management. Given the disorder's complexity, care must be extensive, covering physical, cognitive, educational, and emotional facets. An individualized, coordinated approach, engaging specialists across disciplines and factoring in family needs, is indispensable for long-term planning and continuous support (Liew & Zhuo, 2023). An emerging innovation in CP rehabilitation is dual tasking, especially for spastic CP. This method combines a motor task, like walking, with a cognitive task, simulating real-world multitasking challenges. Dual tasking might improve both motor and cognitive performance, given its realistic approach. A carefully designed clinical trial assessing dual-tasking's efficacy could revolutionize spastic CP treatment, potentially enhancing both physical and cognitive aspects of the condition (Mendoza-Sengco et al., 2023).

Ochandorena-Acha et al. (2022) combined virtual reality (VR) with treadmill training to assess potential treatment benefits for children with spastic cerebral palsy. The research delved into aspects like walking, stability, balance, and emotional implications (Ochandorena-Acha et al., 2022). Similarly, Liu et al. (2022) explored VR's effectiveness on cerebral palsy (CP) children, reviewing 16 studies. The findings revealed improvements in balance and mobility but also indicated inconclusive evidence about VR's impact on daily life skills (Liu et al., 2022). In exploring dual tasking's role in cerebral palsy, Lee et al. (2021) studied the relationship between dual tasking, gait, and cognition. Results showed that CP children exhibit differences from typically developing counterparts when multitasking (Lee et al., 2021). Furthermore, Roostaei et al. (2021) analyzed the effects of dual motor tasks on children, particularly those with spastic diplegia (Roostaei et al., 2021). The study suggested that dual tasking's efficacy might vary based on the CP type, emphasizing tailored therapeutic strategies.

Kelders et al. (2018) investigated attention dynamics in CP children during walking and standing, integrating game-based elements with balance training

(Kelders et al., 2018). Hagmann-von Arx et al. (2016) paired visual cognitive tasks with gait training, observing improvements in balance and gait for diplegic CP children (Hagmann-von Arx et al., 2016). Gauge and Novacheck's (2001) study on dual-tasking in CP management highlighted the need for standardized metrics, enhanced research sample sizes, and longitudinally designed studies to solidify understanding and optimize therapeutic strategies (Gage & Novacheck, 2001).

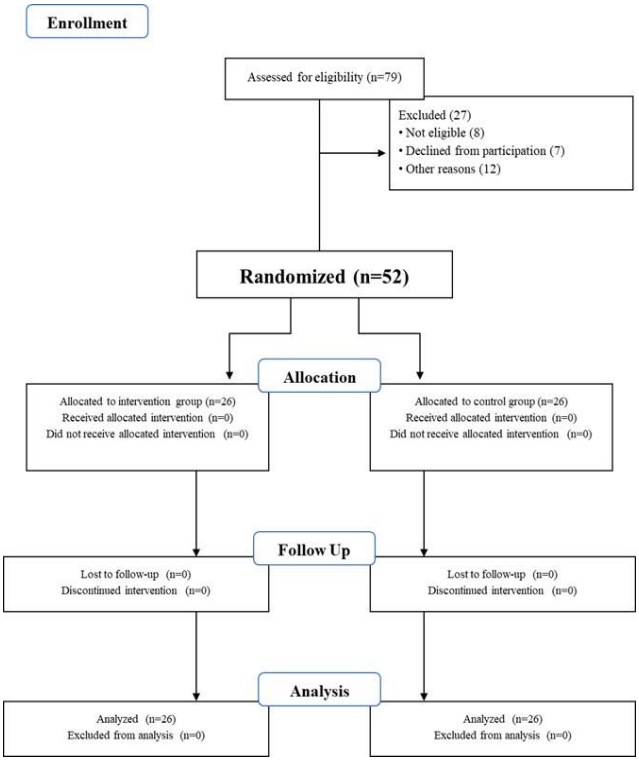
The burgeoning interest in innovative therapies, especially dual tasking and virtual reality, underscores the significance of understanding and ameliorating the challenges faced by children with cerebral palsy (CP). While studies like those of Ochandorena-Acha et al. (2022) and Liu et al. (2022) have begun to navigate these uncharted waters, there exists a pronounced gap in standardized metrics, longitudinal effects, and tailored therapeutic strategies (Ochandorena-Acha et al., 2022). To address these research lacunae, there's a compelling need for comprehensive studies that juxtapose cognitive and motor dual task training's impacts on various CP subtypes. The overarching objective, then, is to cement an evidence-based foundation for therapeutic interventions, aiming for enhanced quality of life and functional independence for CP children.

MATERIAL AND METHODS

The study was a Randomized Control Trial conducted over nine months, following the approval of the synopsis, in the Physiotherapy Department of Allama Iqbal Memorial Hospital, Gujranwala. The primary sample size was estimated at 44 based on the clinical trials guidelines set by the Faculty of Health Sciences, University of Lahore. However, to account for potential dropouts (20%), the total sample size was adjusted to 52, with 26 participants in each group (Lee et al., 2021).

Participants were meticulously selected through a non-probability, purposive sampling technique. They were children aged between 6–12 years (Paneth, 2023) diagnosed with spastic cerebral palsy (Romeo et al., 2023). Furthermore, their score on the Gross Motor Function Classification System (GMFCS) was between II-III, and they showcased both an ability to understand commands and willingness to cooperate during examinations. Any child with a diagnosis of a progressive neurological disorder, other severe concurrent illnesses unrelated to CP, recent history of major

surgeries, or inability to endure the isokinetic test was excluded from the study. For the allocation of participants into the two groups, a computerized randomization method was utilized, with random numbers software generating the sequence. Conducted as a single-blinded study, participants in the experimental group were not privy to the treatment modalities of the control group.



Group A, the control group, embarked on a conventional therapy regimen designed for patients with spastic cerebral palsy. This therapeutic approach aimed to set a baseline for the patient's abilities, notably in balance and gait, to observe any changes without the influence of experimental techniques. In contrast, Group B underwent an experimental Motor and Cognitive Dual Task Gait Training. The dual tasking involved participants walking on a treadmill or overground, performing a series of five distinct motor or cognitive tasks, each lasting three minutes (Lee et al., 2021).

The study rigorously adhered to ethical considerations. The ethical committee of the University of Lahore defined the guidelines, with emphasis on informed consent from participants' legal guardians and ensuring the confidentiality of all participants. All data were carefully safeguarded, and participants were reminded of their right to withdraw at any stage without repercussions. The study adhered to the principles of the Declaration of Helsinki, and prior to commencement, the protocol underwent a thorough review and approval from the institutional ethical board. Upon completion of the interventions, data were collated and processed using SPSS version 25. Quantitative variables like age, weight, and height were represented as mean ± SD, while qualitative variables were displayed in terms of frequency and percentage. To determine the efficacy of the interventions, repeated measure ANOVA tests were

conducted, comparing outcomes at different follow-up intervals. Any p-value less than or equal to 0.5 was deemed significant. Assessments were made three times: initially before treatment for a baseline reading, after 4 weeks, and finally after 6 weeks marking the end of the interventions.

RESULTS

Variables	Categories / Units	Conventional Therapy Group	Dual Task Gait Training Group	p-value
Gender	Male	12 (46.2%)	15 (57.7%)	0.92
	Female	14 (53.8%)	11 (42.3%)	0.96
Socioeconomic status	Upper	12 (46.2%)	10 (38.5%)	0.94
	Middle	8 (30.8%)	14 (53.8%)	0.95
	Lower	6 (23.1%)	2 (7.7%)	0.83
Age (years)		8.54±2.08	8.6154±1.90	0.75
Weight (kg)		24.12±5.18	24.1923±4.89	0.8
Height (cm)		126.15±25.62	126.5385±23.82	0.7
Body Mass Index		20.37±3.17	20.3942±3.05	0.98

In terms of gender distribution, the Conventional Therapy Group (CTG) consisted of 46.2% males and 53.8% females, while the Dual Task Gait Training Group (DTGTG) had 57.7% males and 42.3% females. Regarding socioeconomic status, the CTG had 46.2% from the upper, 30.8% from the middle, and 23.1% from the lower categories, in contrast to 38.5%, 53.8%, and 7.7% in the DTGTG, respectively. The average age was 8.54±2.08 years for CTG and 8.6154±1.90 years for DTGTG. Participants in CTG weighed an average of 24.12±5.18 kg and had a height of 126.15±25.62 cm, with a Body Mass Index (BMI) of 20.37±3.17. For DTGTG, the average weight was 24.1923±4.89 kg, height was 126.5385±23.82 cm, and the BMI was 20.3942±3.05.

Outcome Variables	Timepoint	Conventional Therapy Median (IQR)	Dual Task Gait Training Median (IQR)	Z-Value	P-Value
Gait Profile Score (GPS)	Baseline	3 (1)	3 (0.25)	-.827	.408
	Week 4	5 (1)	5.5 (0.5)	-2.555	.011
	Week 8	6.5 (1.5)	8 (2)	-3.736	.000
Pediatric Berg Balance Scale (PBS)	Baseline	26 (4.25)	26 (5.25)	-.285	.775

Outcome Variables	Timepoint	Conventional Therapy Median (IQR)	Dual Task Gait Training Median (IQR)	Z-Value	P-Value
	Week 4	33 (3)	37.5 (3)	-3.402	.001
	Week 8	37 (3)	41 (4)	-3.279	.001
GMFCS	Baseline	3 (0)	3 (1)	-1.516	.130
	Week 4	3 (1)	2 (0)	-3.993	.000
	Week 8	2 (1)	1 (0)	-3.481	.001
Social Well-Being	Baseline	42 (14)	42 (14)	-.138	.890
	Week 4	48.5 (12.75)	56 (26.25)	-2.346	.019
	Week 8	54.5 (17)	67.5 (25)	-3.744	.000
Functioning	Baseline	42 (14)	56 (14)	-1.668	.095
	Week 4	51 (2.25)	70 (12.25)	-4.442	.000
	Week 8	57 (1)	81.5 (12.5)	-4.972	.000
Participation and Physical Health	Baseline	42 (14)	42 (14)	-.530	.596
	Week 4	50 (13)	58 (14)	-2.640	.008
	Week 8	55 (11.75)	70.5 (14)	-3.779	.000
Emotional Well-Being and Self-Esteem	Baseline	42 (14)	42 (13.5)	-.118	.906
	Week 4	48.5 (11.75)	57 (3.75)	-1.798	.072
	Week 8	54.5 (12)	69 (5.5)	-3.297	.001
Pain and Impact of Disability	Baseline	42 (14)	42 (28)	-.497	.619
	Week 4	49 (12)	57 (13.25)	-2.494	.013
	Week 8	56 (12.25)	69 (11.25)	-3.473	.001
Access to Services	Baseline	42 (14)	49 (28)	-1.362	.173
	Week 4	50 (13.25)	64.5 (19.5)	-3.245	.001
	Week 8	56.5 (14)	77 (19.5)	-4.199	.000
Family Health	Baseline	56 (14)	56 (14)	-.662	.508
	Week 4	63 (15)	71 (13)	-2.658	.008
	Week 8	70 (15)	83 (12.75)	-3.812	.000
CP-QOL	Baseline	44 (2)	44 (2)	-1.504	.133
	Week 4	51 (2)	60 (2.75)	-5.931	.000

Outcome Variables	Timepoint	Conventional Therapy Median (IQR)	Dual Task Gait Training Median (IQR)	Z-Value	P-Value
	Week 8	58 (2)	72 (3.25)	-6.194	.000

The outcome variables recorded at Baseline, Week 4, and Week 8 reveal marked differences between the Conventional Therapy and Dual Task Gait Training groups. By Week 8, the Gait Profile Score (GPS) for the Dual Task group reached 8, whereas the Conventional group only managed 6.5 ($p<.001$). The Pediatric Berg Balance Scale (PBS) results at Week 8 were 41 for the Dual Task group and 37 for the Conventional group ($p<.001$). By Week 8, the GMFCS had the Dual Task group at a median score of 1, superior to the Conventional group's 2 ($p<.001$). In Week 8, Social Well-Being scores favored the Dual Task group with 67.5 over the Conventional group's 54.5 ($p<.001$), while the Functioning scores stood at 81.5 for the Dual Task group, overshadowing the Conventional group's 57 ($p<.001$).

	Conventional Therapy Group		Dual Task Gait Training Group	
Variable	Rank (Mean)	p-value	Rank (Mean)	p-value
Baseline: Gait Profile Score (GPS)	1.15	0.000	1.02	0.000
Week 4 & 8: Gait Profile Score (GPS)	1.87		1.98	
Baseline: Pediatric Berg Balance Scale (PBS)	1.00	0.000	1.00	0.000
Week 4 & 8: Pediatric Berg Balance Scale (PBS)	2.00		2.13	
Baseline: GMFCS	2.71	0.000	3.00	0.000
Week 4 & 8: GMFCS	2.19		1.96	
Baseline: Social well-being and acceptance	1.00	0.000	1.00	0.000
Week 4 & 8: Social well-being and acceptance	2.00		2.00	
Baseline: Functioning	1.00	0.000	1.00	0.000
Week 4 & 8: Functioning	2.00		2.00	
Baseline: Participation and physical health	1.00	0.000	1.00	0.000

	Conventional Therapy Group		Dual Task Gait Training Group	
Week 4 & 8: Participation and physical health	2.00		2.00	
Baseline: Emotional well-being and self-esteem	1.00	0.000	1.00	0.000
Week 4 & 8: Emotional well-being and self-esteem	2.00		2.00	
Baseline: Pain and impact of disability	1.00	0.000	1.00	0.000
Week 4 & 8: Pain and impact of disability	2.00		2.00	
Baseline: Access to services	1.00	0.000	1.00	0.000
Week 4 & 8: Access to services	2.00		2.00	
Baseline: Family health	1.00	0.000	1.00	0.000
Week 4 & 8: Family health	2.00		2.00	
Baseline: CP-QOL	1.00	0.000	1.00	0.000
Week 4 & 8: CP-QOL	2.00		2.00	

At the baseline, both the Conventional Therapy and Dual Task Gait Training groups exhibited similar ranks across most of the variables with prominent figures like Gait Profile Score (GPS) at 1.15 and 1.02 (both p=0.000) respectively. By weeks 4 & 8, the GPS increased to 1.87 for the Conventional group and 1.98 for the Dual Task group. For the Pediatric Berg Balance Scale (PBS), both groups began at an identical rank of 1.00 (p=0.000) at the baseline and saw an increase by weeks 4 & 8, with the Conventional group at 2.00 and the Dual Task group slightly ahead at 2.13.

The GMFCS rankings at the baseline were 2.71 for the Conventional group and 3.00 for the Dual Task group, both significant at p=0.000. By weeks 4 & 8, the ranks shifted to 2.19 for the Conventional group and 1.96 for the Dual Task group. Other domains, including Social well-being and acceptance, Functioning, Participation and physical health, Emotional well-being and self-esteem, Pain and impact of disability, Access to services, Family health, and CP-QOL, all started with a baseline rank of 1.00 (p=0.000) for both groups. By weeks 4 & 8, they all uniformly advanced to a rank of 2.00 for both therapy groups.

Discussion

In the study titled "Comparative Effects of Motor and Cognitive Dual Task Gait Training on Balance, Spasticity, and Quality of Life in Patients with Diplegic Cerebral Palsy," the researchers explored the impact of dual-task gait training in children with diplegic cerebral palsy. This randomized controlled trial had two main groups: conventional therapy and dual-task gait training (including both cognitive and motor

tasks), with 30 subjects in each. Initial findings showed similar median scores for both groups across metrics like the Gait Profile Score (GPS), Pediatric Berg Balance Scale (PBS), and the Gross Motor Function Classification System (GMFCS). However, by week 8, the Dual Task Gait Training Group showed more pronounced improvements across multiple domains, with significant p-values. For instance, in the GPS and PBS scores, p-values of 0.011 and 0.000 were observed at weeks 4 and 8 respectively. Similar significance was found in GMFCS scores and other parameters like social well-being and the CP-QOL. On the aspect of pain and disability, the Dual Task Gait Training Group reported less pain and disability, particularly at week 8, with significant median scores of 57 ($p=0.013$) and 69 ($p<0.001$) (San Juan & Swaroop, 2022).

Divergences between the findings of this study and previous research were evident. While Zhou et al. (2019) and Hung & Meredith (2014) highlighted challenges in motor control and coordination under dual-task conditions, the DTGT group in this study displayed significant progress in these areas (Hung & Meredith, 2014; Zhou et al., 2019). Novak et al. (2020) posited that multiple interventions are beneficial for cerebral palsy, and the research further solidifies the potential of DTGT (Novak et al., 2020). Okur et al. (2022) examined the impact of dual-task training on gait parameters in children with spastic diplegic cerebral palsy. Their preliminary findings suggested a positive impact, which aligns with our study. The Gait Profile Score improved significantly in our DTGT group, showcasing enhanced motor control and gait (Okur et al., 2022).

Gharib et al. (2017) tested the efficacy of concurrent cognitive-motor training on gait in hemiparetic cerebral palsy through a randomized controlled trial. They concluded that this type of training could be beneficial for patients, a finding that aligns with our study. The considerable improvements in gait, coordination, and balance in our DTGT group support Gharib et al.'s conclusion, and add evidence to the body of literature on the effectiveness of dual-task training.(Gharib et al., 2017). Contradictory results were noted when compared to Quant et al. (2004) and Demirci et al. (2016) regarding the effects of cognitive tasks on balance (Demirci et al., 2016; Quant et al., 2004). However, the research suggests that with systematic training, patients can overcome initial disruptions. A series of other comparisons, including

works from Polat et al. (2021), Villafaina et al. (2018), and Roostaei et al. (2021), further reinforced the efficacy of DTGT in enhancing balance, motor control, and gait in cerebral palsy patients (Polat et al., 2021).

Conclusion

Both Conventional Therapy and Dual Task Gait Training yielded significant improvements, with the latter often outperforming the former. Every measured parameter displayed significant changes by weeks 4 and 8. This research underscores the potential of Dual Task Gait Training in cerebral palsy rehabilitation, but broader applications necessitate more extensive studies. Both Conventional Therapy and Dual Task Gait Training significantly improved outcomes for participants, with the latter showing slightly superior effects in most parameters. Notably, all measures exhibited significant changes from baseline to weeks 4 and 8, demonstrating the interventions' effectiveness. However, these results require further research for broader application. This study illuminates the potential of Dual Task Gait Training as an auxiliary method in cerebral palsy rehabilitation.

RECOMMENDATIONS

•Recommendations for future research include the following:

•Expand sample size and diversity: Future research should aim to recruit a larger and more diverse sample of participants to ensure results are broadly applicable.

•Increase the follow-up period: Extending the assessment period can provide a better understanding of the long-term impacts and effectiveness of these interventions.

•Include more control variables: Future studies should attempt to control for, or at least account for, other factors that may influence outcomes, such as daily physical activity levels, access to additional therapies or treatments, and participants' daily living conditions.

Reference

Dan, B. (2022). Naming cerebral palsy 'CP': Physiology and service provision. *Dev Med Child Neurol*, *64*(11), 1312-1313. https://doi.org/10.1111/dmcn.15378

Demirci, C. S., Kılınç, M., & Yıldırım, S. A. (2016). The effect of dual task on clinical balance performance in ataxia patients.

Elliott, A. M., & Guimond, C. (2022). Genetic counseling considerations in cerebral palsy. *Mol Genet Metab*, *137*(4), 428-435. https://doi.org/10.1016/j.ymgme.2021.07.004

Friedman, J. M., van Essen, P., & van Karnebeek, C. D. M. (2022). Cerebral palsy and related neuromotor disorders: Overview of genetic and genomic studies. *Mol Genet Metab*, *137*(4), 399-419. https://doi.org/10.1016/j.ymgme.2021.11.001

Gage, J. R., & Novacheck, T. F. J. J. o. P. O. B. (2001). An update on the treatment of gait problems in cerebral palsy. *10*(4), 265-274.

Gharib, N. M., Abd-El Maksoud, G. M., Eldin, S., & Elsayed, B. J. I. J. P. R. (2017). Efficacy of concurrent cognitive-motor training on gait in hemiparetic cerebral palsy: a randomized controlled trial. *5*(1), 1852-1862.

Hagmann-von Arx, P., Manicolo, O., Lemola, S., & Grob, A. J. F. i. p. (2016). Walking in school-aged children in a dual-task paradigm is related to age but not to cognition, motor behavior, injuries, or psychosocial functioning. *7*, 352.

Hirides, P. C., Hirides, S. C., & Hirides, C. (2023). Cerebral Palsy and Difficult Birth. A Scoping Review. *J Neonatal Perinatal Med*, *16*(2), 209-219. https://doi.org/10.3233/npm-230043

Hodgson, K. A., Manley, B. J., & Cheong, J. L. Y. (2023). Cerebral palsy and postnatal steroids-Reply. *Acta Paediatr*, *112*(6), 1353. https://doi.org/10.1111/apa.16743

Hung, Y.-C., & Meredith, G. S. J. R. i. d. d. (2014). Influence of dual task constraints on gait performance and bimanual coordination during walking in children with unilateral cerebral palsy. *35*(4), 755-760.

Hunt, M., Everaert, L., Brown, M., Muraru, L., Hatzidimitriadou, E., & Desloovere, K. (2022). Effectiveness of robotic exoskeletons for improving gait in children with cerebral palsy: A systematic review. *Gait Posture*, *98*, 343-354. https://doi.org/10.1016/j.gaitpost.2022.09.082

Kelders, S. M., Sommers-Spijkerman, M., & Goldberg, J. J. J. o. m. I. r. (2018). Investigating the direct impact of a gamified versus nongamified well-being intervention: an exploratory experiment. *20*(7), e9923.

Kruse, A., Habersack, A., Jaspers, R. T., Schrapf, N., Weide, G., Svehlik, M., & Tilp, M. (2022). Acute Effects of Static and Proprioceptive Neuromuscular Facilitation Stretching of the Plantar Flexors on Ankle Range of Motion and Muscle-Tendon Behavior in Children with Spastic Cerebral Palsy-A Randomized Clinical Trial. *Int J Environ Res Public Health*, *19*(18). https://doi.org/10.3390/ijerph191811599

Lee, N.-Y., Lee, E.-J., & Kwon, H.-Y. J. J. o. e. r. (2021). The effects of dual-task training on balance and gross motor function in children with spastic diplegia. *17*(1), 21.

Liew, Z., & Zhuo, H. (2023). Cerebral Palsy and Maternal Injury During Pregnancy. *JAMA Pediatr*, *177*(1), 10-11. https://doi.org/10.1001/jamapediatrics.2022.4541

Liu, C., Wang, X., Chen, R., & Zhang, J. (2022). The Effects of Virtual Reality Training on Balance, Gross Motor Function, and Daily Living Ability in Children With Cerebral Palsy: Systematic Review and Meta-analysis [Review]. *JMIR Serious Games*, *10*(4), e38972. https://doi.org/10.2196/38972

McIntyre, S., Goldsmith, S., Webb, A., Ehlinger, V., Hollung, S. J., McConnell, K., . . . Himmelmann, K. (2022). Global prevalence of cerebral palsy: A systematic analysis. *Dev Med Child Neurol*, *64*(12), 1494-1506. https://doi.org/10.1111/dmcn.15346

Mendoza-Sengco, P., Lee Chicoine, C., & Vargus-Adams, J. (2023). Early Cerebral Palsy Detection and Intervention. *Pediatr Clin North Am*, *70*(3), 385-398. https://doi.org/10.1016/j.pcl.2023.01.014

Mohanty, T., Joseph, S. D., Gunasekaran, P. K., Doreswamy, S. M., & Saini, L. (2023). Predictors of Risk for Cerebral Palsy: A Review. *Pediatr Phys Ther*, *35*(3), 347-357. https://doi.org/10.1097/pep.0000000000001020

Novak, I., Morgan, C., Fahey, M., Finch-Edmondson, M., Galea, C., Hines, A., . . . reports, n. (2020). State of the evidence traffic lights 2019: systematic review of interventions for preventing and treating children with cerebral palsy. *20*(2), 1-21.

Ochandorena-Acha, M., Terradas-Monllor, M., Nunes Cabrera, T. F., Torrabias Rodas, M., & Grau, S. (2022). Effectiveness of virtual reality on functional mobility during treadmill training in children with cerebral palsy: a single-blind, two-arm parallel group randomised clinical trial (VirtWalkCP Project). *BMJ Open*, *12*(11), e061988. https://doi.org/10.1136/bmjopen-2022-061988

Okur, E. O., Arik, M. I., Okur, I., Gokpinar, H. H., Gunel, M. K. J. G., & Posture. (2022). Dual-task training effect on gait parameters in children with spastic diplegic cerebral palsy: Preliminary results of a self-controlled study. *94*, 45-50.

Oliva-Sierra, M., Ríos-León, M., Abuín-Porras, V., & Martín-Casas, P. (2022). [Effectiveness of mirror therapy and action observation therapy in infantile cerebral palsy: a systematic review]. *An Sist Sanit Navar*, *45*(2). https://doi.org/10.23938/assn.1003

Paneth, N. (2023). Cerebral palsy as a public health indicator. *Paediatr Perinat Epidemiol*, *37*(5), 413-414. https://doi.org/10.1111/ppe.12977

Polat, A. P., Cengiz, D. U., Cimen, H., Tezcan, E. I., & Tombuloglu, C. (2021). The effects of additional cognitive and motor tasks on static and dynamic balance in school-age children.

Quant, S., Adkin, A. L., Staines, W. R., Maki, B. E., & McIlroy, W. E. J. B. n. (2004). The effect of a concurrent cognitive task on cortical potentials evoked by unpredictable balance perturbations. *5*(1), 1-12.

Romeo, D. M., Venezia, I., Pede, E., & Brogna, C. (2023). Cerebral palsy and sex differences in children: A narrative review of the literature. *J Neurosci Res*, *101*(5), 783-795. https://doi.org/10.1002/jnr.25020

Roostaei, M., Raji, P., Morone, G., Razi, B., Khademi-Kalantari, K. J. J. o. b., & therapies, m. (2021). The effect of dual-task conditions on gait and balance performance

in children with cerebral palsy: A systematic review and meta-analysis of observational studies. *26*, 448-462.

San Juan, A. M., & Swaroop, V. T. (2022). Cerebral Palsy: Hip Surveillance. *Pediatr Ann*, *51*(9), e353-e356. https://doi.org/10.3928/19382359-20220706-06

Villafaina, S., Collado-Mateo, D., Domínguez-Muñoz, F. J., Fuentes-García, J. P., & Gusi, N. J. M. (2018). Impact of adding a cognitive task while performing physical fitness tests in women with fibromyalgia: A cross-sectional descriptive study. *97*(51).

Zhou, J., Lowe, E., Cahill-Rowley, K., Mahtani, G., Young, J., & Rose, J. J. J. o. C. s. O. (2019). Influence of impaired selective motor control on gait in children with cerebral palsy. *13*(1), 73-81.