Review Article

Effects of Physical Therapy Management on Gross Motor Function and Spasticity among Diplegic Cerebral Palsy

Hamza Ahmed[1], Muhammad Abid Khan[1*], Syed Meeran Hasnain[1], Raman Kumar[2], Fouzia Hussain[1]

1. Department of Physical Therapy, Faculty of Allied Health Sciences, Ziauddin College of Physical Therapy, Ziauddin University, Karachi, Pakistan.
2. Liaquat National Hospital and Medical College, Karachi, Pakistan.

Use your device to scan and read the article online

Citation Ahmed H, Khan MA, Hasnain SM, Kumar R, Hussain F. Effects of Physical Therapy Management on Gross Motor Function and Spasticity Among Diplegic Cerebral Palsy. Journal of Modern Rehabilitation. 2025;19(3):211-226. http://dx.doi.org/10.18502/jmr.v19i3.19083

http://dx.doi.org/10.18502/jmr.v19i3.19083

Article info:
Received: 22 Dec 2024
Accepted: 26 Apr 2025
Available Online: 01 Jul 2025

ABSTRACT

Introduction: Cerebral palsy (CP) is a leading cause of disability among the pediatric population, especially in Asia. Permanent disability is mostly due to spasticity and poor gross motor function, which adds a significant socioeconomic burden to the healthcare system. This study aims to evaluate the effectiveness of physical therapy-based interventions in improving gross motor function and reducing spasticity.

Materials and Methods: From February to July 2024, a thorough search was conducted on CINAHL, PubMed, PEDro, Web of Science and Scopus for studies assessing spasticity using the modified Ashworth scale (MAS) and gross motor function using the gross motor function measure (GMFM)-88 standing/walking dimensions in children with diplegic CP. Seventeen eligible trials were analyzed using fixed/random-effects models in MedCalc.

Results: The analysis showed significant improvements in walking ability P<0.0001 (confidence interval [CI] 95%, 0.20%, 0.50%], standardized mean differences [SMD]=0.563, Q=43.9325) and standing ability P=0.0004 (CI 95%, 0.20%, 0.50%, SMD=0.187, Q=22.5239) in the experimental group (EG), as measured using the GMFM-88. However, no significant impact was observed on any dimension of the GMFM-88 P=0.5821 (CI 95%, -0.0508%, 0.301%, SMD=0.125, Q=6.5843). According to the MAS, interventions targeting spasticity reduction showed no significant effects P=0.1018 (CI 95%, 0.20%, 0.50%, SMD=0.306, Q=10.5922).

Conclusion: This meta-analysis reveals that modified suit therapy, vibration therapy, and hippotherapy enhance standing and walking in GMFM-88 but did not reveal significant effects of physical therapy interventions in improving overall gross motor function or reducing spasticity in children with diplegic CP.

Keywords:

Diplegic cerebral palsy; Spasticity; Hippotherapy; Myofascial release; Gross motor function

*** Corresponding Author:**
Muhammad Abid Khan, Assistant Professor.
Address: *Department of Physical Therapy, Faculty of Allied Health Sciences, Ziauddin College of Physical Therapy, Ziauddin University, Karachi, Pakistan.*
Tel: *+92 (314) 2106864*
E-mail: *abid.khan@zu.edu.pk*

Introduction

Globally, 0.9% of the population has cerebral palsy (CP) [1]. However, prevalence rates show regional variation, with high-income countries reporting rates of 0.2% and low-income countries of 0.3% [2]. Based on data from the 2011–2012 and 2011–2013 national survey of children's health and the national health interview survey, the prevalence in the United States was estimated to be 2.6 per 1000 [3], while the prevalence rate of CP in Europe was approximately 0.8 per 10000 live births, which shows a high difference in various regions [4]. Regarding the prevalence of CP in Pakistan, CP is the third most common neurological condition in the child population, accounting for 10.5% of cases. At the same time, epilepsy is the most common neurological condition, affecting 36% of children [5], with a significantly higher frequency of 1.22 per 1000 live births [6]. Spastic diplegic and spastic quadriplegic CP are the most common subtypes in Pakistan, accounting for 39% of cases. In comparison, athetoid (3.34%) and ataxic (10.1%) CP are the next most common subtypes [7].

Individuals with spastic diplegic CP exhibit distinct characteristics, including increased muscle tone, lower extremity scissoring and functional impairment. Scissors in the lower limbs, a common manifestation of spastic diplegic CP, often result from hamstring and gastrocnemius hypertonia [8]. This condition primarily results from spasticity caused by upper motor neuron lesions, resulting in excessive alpha motor neuron activity that increases the stretch reflex and muscle tone [9]. However, spasticity in the lower extremities leads to difficulty in ambulation and directly affects the gross motor function of children with spastic diplegic cerebral [10, 11]. Fortunately, spastic diplegic CP can be managed using various pharmacological and non-pharmacological approaches [12].

Pharmacological management includes oral baclofen and botulinum toxin injections [12]. Surgical interventions, such as intrathecal baclofen and muscle lengthening procedures, are also used to reduce spasticity [12, 13]. However, the intervention showed some adverse effects, including increased spasticity and stomach discomfort [14]. However, physical therapy plays a vital role in the management of spastic diplegic CP. It is critical to improve the outcomes for affected individuals. Various physical therapy approaches have been used effectively, including neurodevelopmental therapies [15], strengthening [16], passive stretching [17], strength training combined with stretching [18], restriction-induced movement therapy, and targeted motor reduction programs [19]. However, a comprehensive meta-analysis was conducted in 2022 among twenty-seven randomized controlled trials (RCTs) with 847 participants and demonstrated that strengthening the lower extremities has a positive impact on functional capabilities and gross motor function, exacerbating spasticity among children with spastic diplegic CP [20]. Spasticity is a crucial component of the CP population. To find a relevant intervention for the reduction of spasticity, a recent meta-analysis conducted among only three RCTs showed that extracorporeal shockwave therapy significantly reduced spasticity [21].

Even though many RCTs on various therapies are available, there remains a lack of comprehensive reviews on interventions for reducing spasticity and enhancing gross motor function among individuals with CP. This meta-analysis addresses this gap by synthesizing an extensive review of various physical therapy interventions to decrease spasticity and enhance gross motor function.

Materials and Methods

Protocol registration

This meta-analysis fulfilled the preferred reporting items for systematic reviews and meta-analysis (PRISMA) requirements [22].

Inclusion criteria

The inclusion criteria for this meta-analysis were based on the population, intervention, outcome and design methodologies [23].

Population

The participants in the studies varied in age from 1 to 22 years and had diplegic CP.

Intervention

Physical therapy interventions, such as modified suit therapy [23], progressive resistance training [24], myofascial release [25], whole body vibration [26], body weight suspension training [27], hippo therapy [28], pediatric aquatic therapy [29], action observation training [30], low- and high-intensity treadmill training [31], virtual reality games [32], Rood approach [33], mobilization [34] and functional strength training [35] were included in this meta-analysis.

Outcome

Gross motor function measure-88 (GMFM-88) dimension D for standing and dimension E for walking, and modified Ashworth scale (MAS).

Design

The study comprised only RCTs.

Exclusion criteria

Studies involving patients with CP receiving therapies other than physical therapy or lacking a control group (CG) were excluded from the analysis. Additionally, the meta-analysis only included research published in English or with accessible translations; papers published before 2011 were excluded.

Data extraction and search strategy

Two researchers thoroughly searched in multiple databases, including CINAHL, PubMed, PEDro, Web of Science and Scopus, between February 2024 and July 2024. The search intended to find publications published between 2011 and 2023. Search techniques were carried out, where keywords (MeSH) were included together with Boolean operators (AND, OR, NOT) in the following ways: "Physical therapy" OR "physiotherapy" OR "physiotherapy exercises" AND "CP" OR "CP" AND "spasticity" AND "gross motor function" OR "GMFM" AND "motor symptoms" OR "standing" AND "walking abilities"

Risk of bias assessment

Various methods were evaluated to verify quality, such as selection bias (randomization and allocation concealment), performance (blinding), attrition bias (missing data), reporting bias (selective reporting results) and other biases and risks. Bias of included studies. A color-coding scheme is used to signify the degree of bias: Green denotes low danger, red denotes high risk, and yellow denotes uncertain risk [36].

Data analysis

MedCalc software, version 18.11.3 was used to analyze the data. To determine the effects of various physical therapy interventions on spasticity and gross motor function, specifically standing and walking dimensions. The meta-analysis included RCTs with baseline and post-treatment data for the physiotherapy and CG. Fixed- and random-effects models were used to estimate the pooled effect size. The scores of the MAS, GMFM-88 and GMFM-88 (dimensions D and E for standing and walking, respectively) were analyzed using the mean, standard deviation and 95% confidence intervals (CI) for the experimental groups (EG) and CG.

Heterogeneity was quantified using the I^2 statistic, with values ranging from 0% to 100%, signifying the degree of heterogeneity. According to the I^2 values, there was minimal variation in the range of 0% to 40%, moderate variation in the range of 30% to 60%, substantial variation in the range of 50% to 90% and large variation in the range of 75% to 100%. A fixed-effects model was employed for modest to moderate heterogeneity and a random-effects model was used for considerable to high heterogeneity. With a significance level of $P<0.05$, effect sizes were categorized as low (0.2 to 00.49), medium (0.5 to 0.79), or large (>0.8) [37].

Results

A comprehensive search of electronic databases, such as CINAHL, PubMed, PEDro, Web of Science and Scopus, identified 661 studies. A selection of 19 full-text articles was added in this meta-analysis by the exclusion of 167 duplicate studies and 387 irrelevant studies that either did not incorporate physical therapy treatments and 76 studies were not retrieved due to several factors, including inaccessible due to paywall, inaccurate or incomplete citation and some are removed from their sources (Figure 1).

Table 1 summarizes the characteristics and findings of the 19 studies included in this review, all of which employed a RCT design to investigate interventions for diplegic CP. The sample sizes varied across studies, with EG and CG ranging from 9 to 45 participants, targeting children and adolescents with diplegic CP. The age range of the participants was 1-22 years. Various interventions were examined, including modified suit therapy, sound-based vibration treatment, progressive resistance training, myofascial release, whole-body vibration, pediatric aquatic therapy, hippotherapy, body-weight suspension training, cross-friction massage, functional massage, equestrian hippo-therapy, traditional massage, action observation training, low-intensity treadmill training, virtual reality games, home-centered activity-based therapy, functional strength training, functional electrical stimulation combined with Rood's ontogenic motor pattern, and Grade III sustained posteroanterior glide to the tibia. At the same time, the talus and calcaneus are fixed. The CG typically received conventional physical therapy. The GMFM-88 was a commonly used outcome

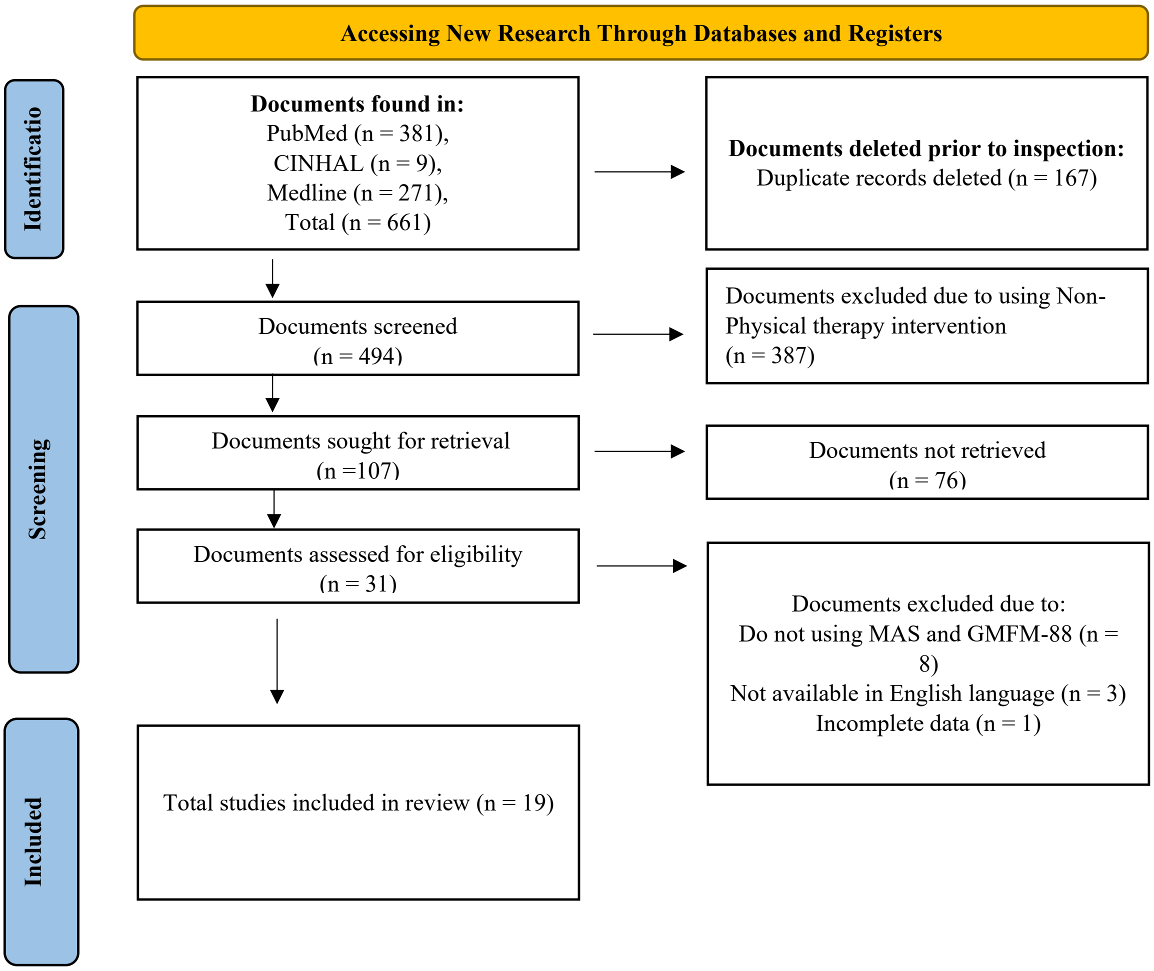

Figure 1. PRISMA flowchart for study selection

JMR

measure, and its dimensions D and E and the MAS for spasticity. The results of these studies suggest that various interventions, such as modified suit therapy, vibration treatment, hippotherapy, functional massage, and traditional massage alongside conventional physical therapy, can improve gross motor function and reduce spasticity in children with diplegic CP. However, some studies have found minimal or no significant effects of progressive resistance training, body-weight suspension training, virtual reality games, and home-centered activity-based therapy (Figure 2).

GMFM-88

Nine studies that examined gross motor function in individuals with CP were included. All studies focused on all dimensions of the GMFM-88, including lying, sitting, rolling, standing, and walking [23, 32-34, 37-39, 41, 42]. The statistical analysis of the GMFM-88 showed no substantial improvement (P=0.5821) in gross abilities associated with the interventions, such as modified suit therapy, sound-based vibration treatment, hippotherapy, functional and traditional massage, functional training and virtual reality games (95% CI, -0.0508%, 0.301%, standardized mean difference [SMD]=0.125). The studies showed low heterogeneity (Q=6.5843, I^2=0.00%), indicating the consistency in the effect size across the studies. Additionally, no substantial publication bias was identified (P=0.5181) (Table 2 and Figure 3).

GMFM-88 (D & E)

The remaining six studies solely focused on CP individuals' walking and standing abilities [24, 27, 30, 31, 43, 44]. The intervention, which included progressive resistance training, body weight suspension therapy, action observation training, low-intensity treadmill training, and functional strength training, was associated with a moderate to larger and significant improvement (P<0.0001) in walking ability (95% CI, 0.20%, 0.50%, SMD=0.563) (Table 3 and Figure 4) and minor but significant improvement (P=0.004) in standing ability (95% CI, 0.20%, 0.50%, SMD=0.187) (Table 4 and Figure 5).

Table 1. Characteristics of the included research

Author (y)	Study Design	Sample Size	Target Population	Age (y)	IG	CG	Outcome Measures	Result
Alagesan et al. 2011 [23]	RCT	EG (15) CG (15)	Diplegic CP	4-12	Modified suit therapy was administered along with conventional therapy for 21 sessions of 2 hours each with 20 minutes of short breaks for 3 weeks.	Conventional therapy has 21 sessions of 2 hours each with 20 minutes of short breaks for 3 weeks.	GMFM-88	Children with spastic diplegic CP can benefit from a combination of modified suit therapy and conventional physiotherapy to enhance their gross motor function.
Katusic et al. 2013 [42]	RCT	EG (45) CG (44)	Diplegic CP	4-6	Sound-based vibration treatment was combined with conventional physical therapy for 12 weeks, with 36 sessions lasting 40 minutes each.	Conventional physical therapy will be conducted throughout 12 weeks, with 36 sessions lasting 40 minutes each.	GMFM-88	Vibration treatment combined with regular physical therapy significantly improved in gross motor function.
Taylor et al. 2013 [24]	RCT	EG (23) CG (25)	Diplegic CP	14-22	Progressive resistance training was conducted in 24 sessions lasting 40 minutes each over 12 weeks.	Conventional physical therapy with 24 sessions lasting 40 minutes each over 12 weeks.	GMFM-88 (D & E)	The findings reveal that progressive resistance training shows minimal variation in the walking and standing abilities among children with diplegic CP
Bhalara et al. 2014 [25]	RCT	EG (9) CG (9)	Diplegic CP	2-8	Myofascial release and stretching were performed in 24 sessions lasting 30 minutes each over 4 weeks.	Stretching combined 24 sessions lasting 30 minutes each over 4 weeks.	MAS	Stretching combined with myofascial release reduces spasticity more effectively than stretching alone.
Ibrahim et al. 2014 [26]	RCT	EG (15) CG (15)	Diplegic CP	8-12	Whole body vibration treatment throughout 12 weeks, with 36 sessions lasting 40 minutes each.	Conventional physical therapy will be conducted throughout 12 weeks, with 36 sessions lasting 40 minutes each.	MAS GMFM-88 (D & E)	This study suggests that whole- body vibration can improve gross motor skills, including standing and walking, without negatively impacting spasticity levels.
Lai et al. 2015 [29]	RCT	EG (11) CG (13)	Diplegic CP	4-12	Pediatric aquatic therapy intervention along with conventional therapy with 24 sessions lasting 60 minutes each over 12 weeks.	Conventional therapy with 24 sessions lasting 30 minutes each over 12 weeks.	MAS	This study could not determine how paediatric aquatic therapy affected the treatment of spasticity.
Kwon et al. 2015 [40]	RCT	EG (45) CG (46)	Diplegic CP	4-10	Hippotherapy along with conventional therapy with 16 sessions lasting 30 minutes each over the 8 weeks.	Conventional therapy with 16 sessions lasting 30 minutes each over the 8 weeks.	GMFM-88	This study shows that in children with diplegic CP, hippotherapy improves gross motor ability.
Emara et al. 2016 [27]	RCT	EG (10) CG (10)	Diplegic CP	6-8	Body-weight suspension training and conventional physical therapy were combined over 12 weeks, with 36 sessions lasting 40 minutes each.	Treadmill training and conventional physical therapy for 12 weeks, with 36 sessions lasting 40 minutes each.	GMFM-88 (D & E)	The study shows that no significant difference was found in standing or walking ability.

Author (y)	Study Design	Sample Size	Target Population	Age (y)	IG	CG	Outcome Measures	Result
Rasool et al. 2017 [45]	Double-blinded RCT	EG (30) CG (30)	Diplegic CP	6-8	Cross-friction massage and conventional physical therapy will be used throughout the course of six weeks in 30 sessions of 30 minutes each.	Conventional physical therapy will be conducted throughout the course of six weeks in 30 sessions of 30 minutes each.	MAS	Deep cross-friction massage is a useful therapeutic approach for controlling spasticity in children with dipelgic CP.
Bingol et al. 2018 [38]	RCT	EG (10) CG (10)	Diplegic CP	5-12	Functional massage, which is 45 minutes long, was administered in 16 sessions over eight weeks in addition to conventional physical therapy.	Conventional physical therapy was administered in 16 sessions, each lasting 45 minutes, over eight weeks.	MAS GMFM-88	The study found that functional messages in conjunction with traditional physiotherapy, can reduce spasticity and increase some motor function parameters in children with diplegic CP.
Lucena-Antón et al. 2018 [2]	RCT	EG (22) CG (22)	Diplegic CP	3-14	The traditional treatment, which included equestrian hippo-therapy, was administered for 12 weeks in 12 sessions, each lasting 45 minutes.	Conventional therapy treatment in 12 weeks of 12 sessions, each lasting 45 minutes, including equestrian hippocampal therapy.	MAS	A hippotherapy-based treatment, in addition to standard therapy in children with diplegic CP, induces statistically significant reductions in hip adductor spasticity.
Mahmood et al. 2019 [39]	RCT	EG (38) CG (37)	Diplegic CP	2-10	Traditional massage and conventional physical therapy have 60 sessions lasting 60 minutes each over 12 weeks.	Conventional physical therapy with 60 sessions lasting 60 minutes each over 12 weeks.	MAS GMFM-88	Traditional massage (TM) can be safely used at home to help children with diplegic CP who are experiencing spasticity; however, it is best when paired with conventional physical therapy (CPT) to enhance gross motor function.
Jeong et al. 2020 [30]	RCT	EG (9) CG (9)	Diplegic CP	5-11	Action observation training: 6 weeks of 18 sessions, each 30 minutes long.	Conventional physical therapy: 6 weeks of 18 sessions, each 30 minutes long.	GMFM-88 (D & E)	These findings imply that action observation training is a practical and advantageous method for enhancing gross motor function in children with CP who have spastic diplegia.
Mattern-Baxter et al. 2020 [31]	RCT	EG (10) CG (9)	Diplegic CP	1-3	Low-intensity treadmill training was conducted in 12 sessions lasting 20 minutes each over 6 weeks.	High-intensity treadmill training was conducted in 12 sessions lasting 20 minutes each over 6 weeks.	GMFM-88 (D & E)	According to the study, children in the high-intensity group had comparable skills at follow-up assessments. However, their improvements in GMFM E scores were comparatively less than those of the low-intensity group immediately after the intervention.

Author (y)	Study Design	Sample Size	Target Population	Age (y)	IG	CG	Outcome Measures	Result
Jha et al. 2021 [32]	RCT	EG (19) CG (19)	Diplegic CP	6-12	Virtual reality games with conventional physical therapy with 24 sessions lasting 60 minutes each over the 6 weeks.	Conventional physical therapy with 24 sessions lasting 60 minutes each over the 6 weeks.	GMFM-88	The study found that for children with diplegic spastic CP, virtual reality gaming, in addition to physical treatment, does not improve gross motor performance or day-to-day functioning more than physical therapy alone.
Goswami et al. 2021 [41]	RCT	EG (30) CG (29)	Diplegic CP	5-12	Home-centered activity-based therapy along with institutional-based physiotherapy with 360 sessions lasting 30 minutes each over 24 weeks.	Institutional-based physiotherapy with 360 sessions lasting 30 minutes each over 24 weeks.	GMFM-88 (D & E)	This study demonstrated that home-centered activity-based therapy is a workable and useful CP rehabilitation approach; however, after 6 months, no apparent gains in gross motor function were seen.
Guru-samy et al. 2022 [44]	RCT	EG (30) CG (29)	Diplegic CP	5-12	Functional strength training was spread over six weeks, with eighteen 45–60-minute sessions.	Conventional physical therapy spread over six weeks, with eighteen 45–60-minute sessions.	GMFM-88 (D & E)	In children with spastic CP, functional strength training enhanced standing and walking abilities.
Babar et al. 2024 [33]	RCT	EG (11) CG (11)	Diplegic CP	3-10	Functional electrical stimulation combined with Rood's ontogenic motor pattern spread over five weeks, with fifteen 45–60-minute sessions.	Conventional physical therapy over five weeks, with fifteen 45–60-minute sessions.	GMFM-88	The study reveals that the functional electrical stimulation with Rood's ontogenic motor pattern enhanced motor functions.
Abush-ameh et al. 2024 [34]	RCT	EG (32) CG (32)	Diplegic CP	4-12	Grade III sustained posteroanterior glide to the tibia while the talus and calcaneus were fixed spread over 4 weeks, with twelve 40-45-minutes sessions.	Conventional physical therapy was administered over 4 weeks, with twelve 40-45-minutes sessions.	GMFM-88	The study found that the mobilization had a greater impact on gross motor function.

JMR

Abbreviations: RCT: Randomized control trial; EG: Experimental group; CP: Cerebral palsy; CG: Control group; MAS: Modified Ashworth scale; GMFM: Gross motor function measure; IG: Intervention Group; CG: Control group.

However, high heterogeneity was observed for standing (Q=22.5239, I^2=77.80%) and walking ability (Q=43.9325, I^2=88.62%), which indicates the variation in the effect size across the studies. Nevertheless, neither the walking (P=0.6677) nor the standing (P=0.2113) abilities showed publication bias.

Spasticity

Furthermore, seven studies focused on spasticity assessment using the MAS in patients with CP [2, 25, 26, 29, 38, 39, 45]. The meta-analysis revealed that a reduction in spasticity was not statistically significant (P=0.1018) associated with interventions, such as functional massage, traditional massage, myofascial release, whole body vibration, pediatric aquatic therapy, cross-friction massage, and equestrian therapy (95% CI, [0.20%, 0.50%, SMD=0.306) (Table 4 and Figure 5). Moderate heterogeneity was found among the studies (Q=10.5922, I^2=43.35%), indicating some variability in the effect size. However, no significant publication bias was detected (P=0.1700) (Table 5 and Figure 6).

The risk of bias

The assessment of the risk of bias in the articles included in the meta-analysis revealed several key findings. Randomization occurred in 18 studies, indicating a strong methodological approach to participant allocation, while only one study had a high risk. Allocation concealment was reported in 12 studies, while it was unclear in seven studies, and high risk was not identified in any study. Blinding of the participants and personnel was performed in eight studies, with eight studies rated as unclear and three at high risk. Incomplete outcome data were assessed as low risk in 16 studies and unclear in one study, with two studies rated as high risk. In 17 trials, the risk of selective reporting was determined to be low, while one was unclear, and one had a low risk. Moreover, 17 investigations disclosed no additional biases; one was unclear, and one had a low risk. These findings indicated a minimal risk of bias across most domains, indicating a high level of evidence in this meta-analysis (Figure 2).

Discussion

This study involved a thorough search of 661 studies, of which 17 were included after removing duplicates and irrelevant studies. The primary objective was to evaluate how different methods or treatment strategies can affect gross motor function measured by GMFM-88 and spasticity measured by MAS.

Regarding gross motor function, including lying, sitting, rolling, standing and walking dimensions, the analysis indicated no substantial improvement (P=0.5821) associated with the interventions, including modified suit therapy, sound-based vibration treatment, hippotherapy, functional and traditional massage, functional training, and virtual reality gaming. The studies showed low heterogeneity, suggesting consistency across the effect size [23, 32-34, 37, 38, 40-42].

+	Low
?	Uncertain
-	High

	Random sequence generation (Selection Bias)	Allocation concealment (Selection Bias)	Blinding of participants and personnel (Performance Bias)	Blinding of outcome assessor (Detection Bias)	Incomplete outcome data (Attrition bias)	Selective reporting (Reporting bias)	Other bias
Alagesan et al. 2011 [23]	+	+	-	+	+	+	+
Katusic et al. 2013 [42]	+	+	-	+	+	+	+
Taylor et al. 2013 [24]	+	+	?	+	+	+	+
Bhalara et al. 2014 [25]	+	?	?	?	+	+	+
Ibrahim et al. 2014 [26]	+	?	?	?	+	+	+
Lai et al. 2015 [29]	+	?	+	?	+	+	+
Kwon et al. 2015 [40]	+	+	+	+	+	+	+
Emara et al. 2016 [27]	+	+	+	?	+	+	+
Rasool et al. 2017 [45]	+	+	+	+	+	+	+
Bingol et al. 2018 [38]	+	+	+	+	+	+	+
Lucena-Antón et al. 2018 [2]	+	+	?	?	+	+	+
Mahmood et al. 2019 [39]	+	+	?	?	+	+	+
Jeong et al. 2020 [30]	+	?	?	?	+	+	+
Mattern-Baxter et al. 2020 [31]	+	?	?	?	+	+	+
Jha et al. 2021 [32]	+	+	+	+	+	+	+
Goswami et al. 2021 [41]	+	+	?	?	?	+	+
Gurusamy et al. 2022 [44]	+	+	+	+	+	+	+
Babar et al. 2024 [33]	+	?	+	+	-	-	?
Abushameh et al. 2024 [34]	-	?	-	-	-	-	-

Figure 2. Risk of bias of mas and GMFM-88.

JMR

Table 2. Random-effects model results for GMFM-88 domains

Study	N1	N2	Total	SMD	SE	95% CI	t	P	% Weight Fixed	% Weight Random
Alagesan et al. 2011 [23]	15	15	30	0.815	0.371	0.0558 to 1.574			5.85	5.85
Katusic et al. 2013 [42]	45	44	89	0.121	0.210	-0.297 to 0.539			18.14	18.14
Kwon et al. 2015 [40]	45	46	91	0.0223	0.208	-0.391 to 0.435			18.57	18.57
Bingol et al. 2018 [38]	10	10	20	-0.228	0.430	-1.131 to 0.675			4.35	4.35
Mahmood et al. 2019 [39]	38	37	75	0.00258	0.229	-0.453 to 0.458			15.36	15.36
Jha et al. 2021 [32]	19	19	38	0.371	0.320	-0.279 to 1.021			7.82	7.82
Goswami et al. 2021 [41]	30	29	59	-0.0886	0.257	-0.603 to 0.426			12.14	12.14
Babar et al. 2024 [33]	11	11	22	0.0390	0.410	-0.817 to 0.895			4.77	4.77
Abushameh et al. 2024 [34]	32	32	64	0.316	0.249	-0.181 to 0.812			13.00	13.00
Total (fixed effects)	245	243	488	0.125	0.0896	-0.0508 to 0.301	1.398	0.163	100.00	100.00
Total (random effects)	245	243	488	0.125	0.0896	-0.0508 to 0.301	1.398	0.163	100.00	100.00
Q	6.5843									
df	8									
P	0.5821									
I^2 (inconsistency)	0.00%									
95% CI for I^2	0.00 to 57.54									
Egger's test: Intercept	1.3805									
Egger's test: 95% CI	-2.6551 to 5.4161									
Egger's test: P	0.4195									

JMR

Abbreviations: GMFM: Gross motor function measure; SMD: Standardized mean difference; SE: Standard error; CI: Confidence interval.

In the studies focusing on dimension D for standing ability, the intervention resulted in a statistically significant improvement (P=0.0004), indicating significant variation in the effect size across the studies [24, 27, 30, 31, 43, 44].

Similarly, in studies that examined dimension E for walking ability, the intervention led to a statistically significant improvement (P<0.0001) with very high heterogeneity [24, 27, 30, 31, 43, 44].

These findings are consistent with those of Yang et al.'s investigation, which also found significant improvement in walking and standing abilities but not in lying, sitting, and rolling abilities [48]. This underscores the need for tailored approaches to address specific motor skill deficits in children with CP. Furthermore, Liang et al. examined the effects of multiple physical therapy exercises on all dimensions of GMFM-88 and reported no significant improvement [46]. A meta-analysis conducted by Salazar et al. to show the effects of neuromuscular electrical stimulation on gross motor function. reported that neuromuscular stimulation

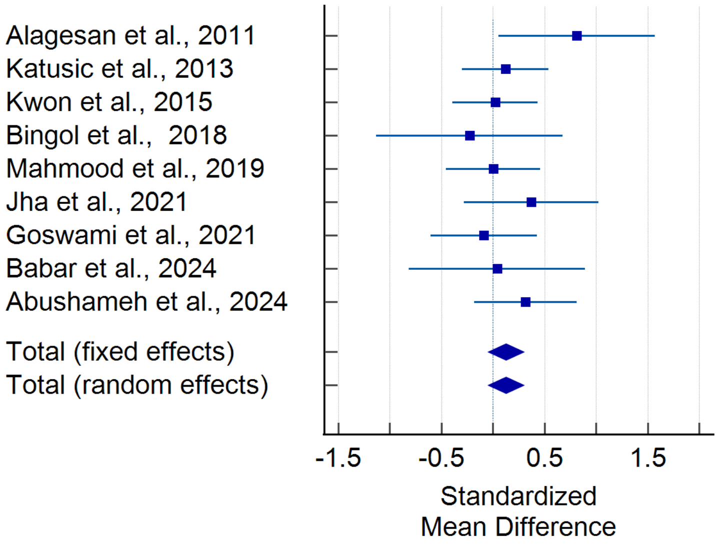

Figure 3. Forest plot to illustrate the GMFM-88

combined with physical therapy exercise showed improvement in the sitting and standing dimensions, but no improvement was found in the walking domain [49].

Additionally, seven studies focused on spasticity assessment using the MAS, showing no significant impact (P=0.1018) on spasticity with interventions, such as functional massage, traditional massage, myofascial release, whole-body vibration, pediatric aquatic therapy, cross-friction massage, and equestrian therapy. Moderate heterogeneity was observed among the studies, indicating some variability in the effect size.

Compared to earlier meta-analyses, such as that by Muazarroh et al. who discovered that massage helped reduce muscle hypertonicity in individuals with CP [50]. Hyen et al. conducted a study demonstrating the short-term benefits of therapeutic horseback riding and hippotherapy on spasticity. Nevertheless, there was no apparent distinction between single trials and repeated sessions [28].

The assessment of the risk of bias in the articles included in the meta-analysis revealed several key findings. Randomization was performed in all seven studies, indicating a strong methodological approach to participant allocation. Allocation concealment was reported in 12 studies, unclear in five studies, and high risk was not identified in any study. Blind-

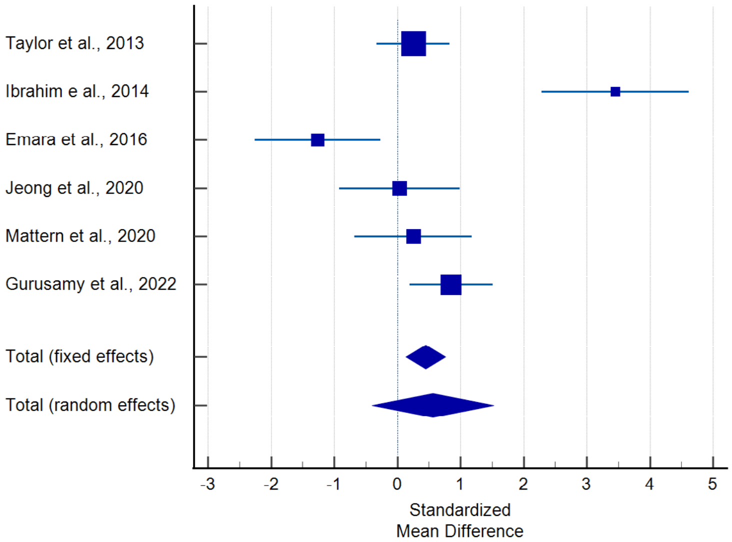

Figure 4. Forest plot to illustrate the GMFM-88 (dimension E for walking)

Table 3. Random-effects analysis of GMFM-88 walking dimension

Study	N1	N2	Total	SMD	SE	95% CI	t	P	% Weight Fixed	% Weight Random
Taylor et al. 2013 [23]	23	24	47	0.252	0.288	-0.328 to 0.833			30.72	17.93
Ibrahim et al. 2014 [25]	15	15	30	3.452	0.570	2.285 to 4.620			7.85	15.18
Emara et al. 2016 [26]	10	10	20	-1.259	0.472	-2.252 to -0.267			11.43	16.23
Jeong et al. 2020 [29]	9	9	18	0.0333	0.449	-0.918 to 0.985			12.65	16.47
Mattern-Baxter et al. 2020 [30]	9	10	19	0.253	0.441	-0.677 to 1.183			13.12	16.55
Gurusamy et al. 2022 [43]	20	20	40	0.854	0.324	0.197 to 1.511			24.24	17.64
Total (fixed effects)	86	88	174	0.449	0.160	0.134 to 0.764	2.811	0.006	100.00	100.00
Total (random effects)	86	88	174	0.563	0.489	-0.402 to 1.528	1.151	0.251	100.00	100.00
Q	43.9325									
DF	5									
P	<0.0001									
I^2 (inconsistency)	88.62%									
95% CI for I^2	77.80 to 94.17									
Egger's test: Intercept	2.6276									
Egger's test: 95% CI	-13.1424 to 18.3977									
Egger's test: P	0.6677									

JMR

Abbreviations: GMFM: Gross motor function measure; SMD: Standardized mean difference; SE: Standard error; CI: Confidence interval.

ing of the participants and personnel was performed in seven studies, with eight studies rated as unclear and two rated as having a high risk of bias. Incomplete outcome data were assessed as low risk in 16 studies and unclear in one study, with no study rated as high risk. In all 17 trials, the risk of selective reporting was low. Moreover, none of the 17 studies disclosed any additional biases. These results indicate a minimal risk of bias across most domains, indicating a high level of evidence for this meta-analysis (Figure 2).

This study offers important information about the effects of different interventions to improve gross motor skills and lower muscle hypertonicity in individuals with CP. It also complies with the PRISMA guidelines and assesses the possibility of bias. Notwithstanding significant limitations, the study's conclusion highlights the importance of an individualized approach in addressing motor skill impairments in the population with CP. It offers additional proof of the effectiveness of these therapies.

Conclusion

The influence of various therapies on the gross motor skills and spasticity of individuals with CP is comprehensively examined in this meta-analysis. This suggests that there has been minimal to moderate improvement in the standing and walking dimensions of GMFM-88, while the interventions, such as modified suit therapy, vibration treatment, hippotherapy, functional massage, and traditional massage alongside conventional physical therapy, can improve gross motor function and reduce spasticity in children with diplegic CP. These outcomes confirm the effectiveness of these therapies and highlight the need for specialized approaches to manage CP.

Table 4. Random-effects analysis of GMFM-88 standing dimension

Study	N1	N2	Total	SMD	SE	95% CI	t	P	% Weight Fixed	% Weight Random
Taylor et al. 2013 [24]	23	24	47	0.373	0.289	-0.210 to 0.956			28.10	18.79
Ibrahim et al. 2014 [26]	15	15	30	1.105	0.383	0.321 to 1.889			16.06	17.00
Emara et al. 2016 [27]	10	10	20	-1.784	0.513	-2.862 to -0.707			8.95	14.45
Jeong et al. 2020 [30]	9	9	18	0.0763	0.449	-0.876 to 1.028			11.67	15.69
Mattern-Baxter et al. 2020 [31]	9	10	19	0.340	0.442	-0.593 to 1.274			12.03	15.82
Gurusamy et al. 2022 [44]	20	20	40	0.663	0.319	0.0176 to 1.308			23.18	18.25
Total (fixed effects)	86	88	174	0.326	0.153	0.0233 to 0.629	2.125	0.035	100.00	100.00
Total (random effects)	86	88	174	0.187	0.335	-0.474 to 0.848	0.559	0.577	100.00	100.00
Q	22.5239									
DF	5									
P	0.0004									
I^2 (inconsistency)	77.80%									
95% CI for I^2	50.85 to 89.97									
Egger's test: Intercept	-5.7838									
Egger's test: 95% CI	-16.5851 to 5.0174									
Egger's test: P	0.2113									

JMR

Abbreviations: GMFM: Gross motor function measure; SMD: Standardized mean difference; SE: Standard error; CI: Confidence interval.

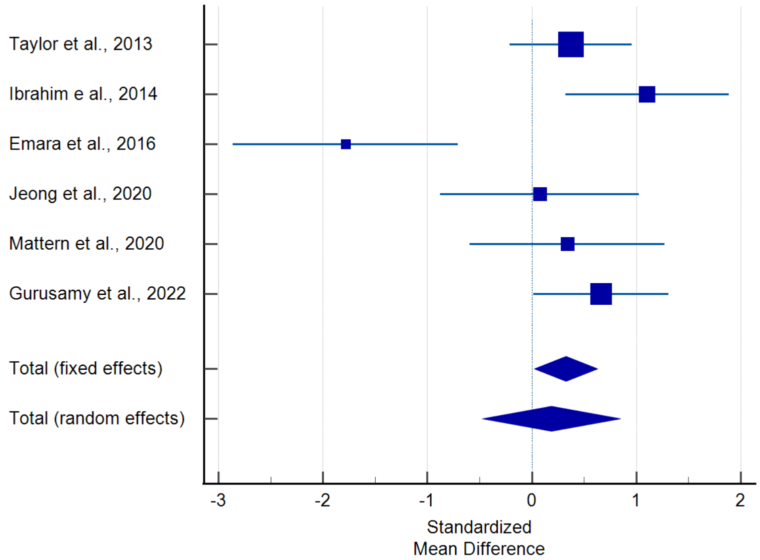

Figure 5. Forest plot to illustrate the GMFM-88 (dimension D

JMR

Table 5. Random-effects model results for MAS

Study	N1	N2	Total	SMD	SE	95% CI	t	P	% Weight Fixed	% Weight Random
Bhalara et al. 2014 [25]	9	9	18	-0.358	0.453	-1.318 to 0.602			7.15	9.71
Ibrahim et al. 2014 [26]	15	15	30	-0.354	0.358	-1.088 to 0.380			11.43	13.26
Lai et al. 2015 [29]	11	13	24	0.564	0.404	-0.274 to 1.401			8.99	11.38
Rasool et al. 2017 [45]	30	30	60	-0.841	0.266	-1.374 to -0.309			20.70	18.25
Bingol et al. 2018 [38]	10	10	20	-0.160	0.429	-1.061 to 0.742			7.97	10.48
Lucena-Antón et al. 2018 [2]	22	22	44	-0.0345	0.296	-0.632 to 0.563			16.73	16.44
Mahmood et al. 2019 [39]	38	37	75	-0.549	0.233	-1.014 to -0.0852			27.03	20.48
Total (fixed effects)	135	136	271	-0.357	0.121	-0.595 to -0.118	-2.944	0.004	100.00	100.00
Total (random effects)	135	136	271	-0.306	0.167	-0.635 to 0.0226	-1.834	0.068	100.00	100.00
Q						10.5922				
DF						6				
P						0.1018				
I^2 (inconsistency)						43.35%				
95% CI for I^2						0.00 to 76.18				
Egger's test: Intercept						3.0465				
Egger's test: 95% CI						-1.8412 to 7.9343				
Egger's test: P						0.1700				

JMR

Abbreviations: GMFM: Gross motor function measure; SMD: Standardized mean differences; SE: Standard error; CI: Confidence interval.

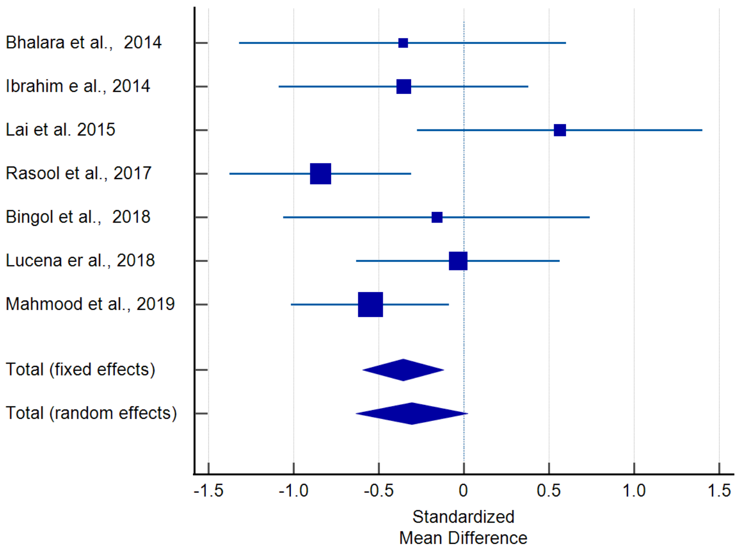

Figure 6. Forest plot to illustrate the MAS

JMR

Recommendations

The results of the current study point to the need for more research to ascertain if interventions for CP with spastic diplegia might successfully enhance gross motor abilities and reduce spasticity. Longitudinal research with long-term results is necessary to investigate sustainability and its influence on quality of life. To tailor therapy for optimal efficacy and patient satisfaction, future research should examine parameters including age, degree of spasticity, and comorbidities.

Limitations

When analyzing the outcomes, it is essential to consider certain constraints. Functional outcomes and quality of life are significant factors in treatment planning; however, the study did not assess the effects of any particular intervention on these variables. Furthermore, the study did not consider confounding factors affecting the results, including comorbidities or concomitant medications.

Ethical Considerations

Compliance with ethical guidelines

This study was documented in the global PROSPERO database (Registration No.: CRD42024535904).

Funding

This research did not receive any grant from funding agencies in the public, commercial, or non-profit sectors.

Authors' contributions

Conceptualization and methodology: Hamza Ahmed, and Muhammad Abid Khan; Investigation and supervision: Muhammad Abid Khan, and Fouzia Hussain; Writing the original draft: Meeran Hasnain and Raman Kumar; Review and editing: Fouzia Hussain.

Conflict of interest

The authors declared no conflict of interest.

Acknowledgments

The authors thank all researchers worldwide for contributing to physical therapy management in diplegic CP.

References

[1] Olusanya BO, Smythe T, Ogbo FA, Nair MKC, Scher M, Davis AC. Global prevalence of developmental disabilities in children and adolescents: A systematic umbrella review. Frontiers in Public Health. 2023; 11:1122009. [DOI:10.3389/fpubh.2023.1122009] [PMID]

[2] Lucena-Antón D, Rosety-Rodríguez I, Moral-Munoz JA. Effects of a hippotherapy intervention on muscle spasticity in children with cerebral palsy: A randomized controlled trial. Complementary Therapies in Clinical Practice. 2018; 31:188-92. [DOI:10.1016/j.ctcp.2018.02.013] [PMID]

[3] Maenner MJ, Blumberg SJ, Kogan MD, Christensen D, Yeargin-Allsopp M, Schieve LA. Prevalence of cerebral palsy and intellectual disability among children identified in two US National Surveys, 2011-2013. Annals of Epidemiology. 2016; 26(3):222-6. [DOI:10.1016/j.annepidem.2016.01.001] [PMID]

[4] Arnaud C, Ehlinger V, Perraud A, Kinsner-Ovaskainen A, Klapouszczak D, Himmelmann K, et al. Public health indicators for cerebral palsy: A European collaborative study of the surveillance of cerebral palsy in Europe network. Paediatric and Perinatal Epidemiology. 2023; 37(5):404-12. [DOI:10.1111/ppe.12950] [PMID]

[5] Chand P, Sultan T, Kulsoom S, Jan F, Ibrahim S, Mukhtiar K, et al. Spectrum of common pediatric neurological disorders: A cross-sectional study from three tertiary care centres across Pakistan. Pediatric Neurology. 2023; 138:33-7. [DOI:10.1016/j.pediatrneurol.2022.09.005] [PMID]

[6] Ahmad A, Akhtar N, Ali H. Prevalence of cerebral palsy in children of district Swabi, Khyber Pakhtunkhwa-Pakistan. Khyber Medical University Journal. 2017; 9(2):88-91. [Link]

[7] Rafique A, Naz H. A survey-based report on the occurrence of cerebral palsy in Urban areas of Karachi. The Journal of the Pakistan Medical Association. 2020; 70(8):1442-4. [DOI:10.5455/JPMA.28135] [PMID]

[8] Manikowska F, Brazevič S, Jóźwiak M, Lebiedowska MK. The role of knee flexors hypertonia in the decision-making of hamstring lengthening surgery for individuals with cerebral palsy. Applied Sciences. 2022; 12(18):9210 [DOI:10.3390/app12189210]

[9] Ayala L, Winter S, Byrne R, Fehlings D, Gehred A, Letzkus L, et al. Assessments and interventions for spasticity in infants with or at high risk for cerebral palsy: A systematic review. Pediatric Neurology. 2021; 118:72-90. [DOI:10.1016/j.pediatrneurol.2020.10.014] [PMID]

[10] Park EY. Path analysis of strength, spasticity, gross motor function, and health-related quality of life in children with spastic cerebral palsy. Health and Quality of Life Outcomes. 2018; 16(1):70. [DOI:10.1186/s12955-018-0891-1] [PMID]

[11] Ko J, Kim M. Reliability and responsiveness of the gross motor function measure-88 in children with cerebral palsy. Physical Therapy. 2013; 93(3):393-400. [DOI:10.2522/ptj.20110374] [PMID]

[12] Parveen S. Management and treatment for cerebral palsy in children's. Indian Journal of Pharmacy Practice. 2018; 11(2):104-9. [DOI:10.5530/ijopp.11.2.23]

[13] Nahm NJ, Graham HK, Gormley ME Jr, Georgiadis AG. Management of hypertonia in cerebral palsy. Current Opinion in Pediatrics. 2018; 30(1):57-64. [DOI:10.1097/MOP.0000000000000567] [PMID]

[14] Bohn E, Goren K, Switzer L, Falck-Ytter Y, Fehlings D. Pharmacological and neurosurgical interventions for individuals with cerebral palsy and dystonia: A systematic review update and meta-analysis. Developmental Medicine and Child Neurology. 2021; 63(9):1038-50. [DOI:10.1111/dmcn.14874] [PMID]

[15] Tekin F, Kavlak E, Cavlak U, Altug F. Effectiveness of neuro-developmental treatment (bobath concept) on postural control and balance in cerebral palsied children. Journal of Back and Musculoskeletal Rehabilitation. 2018; 31(2):397-403. [DOI:10.3233/BMR-170813] [PMID]

[16] Novak I, Morgan C, Fahey M, Finch-Edmondson M, Galea C, Hines A, et al. State of the evidence traffic lights 2019: Systematic review of interventions for preventing and treating children with cerebral palsy. Current Neurology and Neuroscience Reports. 2020; 20(2):3. [DOI:10.1007/s11910-020-1022-z] [PMID]

[17] Kalkman BM, Bar-On L, Cenni F, Maganaris CN, Bass A, Holmes G, et al. Muscle and tendon lengthening behaviour of the medial gastrocnemius during ankle joint rotation in children with cerebral palsy. Experimental Physiology. 2018; 103(10):1367-76. [DOI:10.1113/EP087053] [PMID]

[18] Crăciun M, Midrigan N. Effectiveness of physical therapy interventions for children with cerebral palsy. Annals of "Dunarea de Jos" University of Galati Fascicle XV, Physical Education and Sport Management. 2020; 1:21-6. [DOI:10.35219/efms.2020.1.04]

[19] Merino-Andrés J, García de Mateos-López A, Damiano DL, Sánchez-Sierra A. Effect of muscle strength training in children and adolescents with spastic cerebral palsy: A systematic review and meta-analysis. Clinical Rehabilitation. 2022; 36(1):4-14. [DOI:10.1177/02692155211040199] [PMID]

[20] Chang MC, Choo YJ, Kwak SG, Nam K, Kim SY, Lee HJ, et al. Effectiveness of extracorporeal shockwave therapy on controlling spasticity in cerebral palsy patients: A meta-analysis of timing of outcome measurement. Children. 2023; 10(2):332. [DOI:10.3390/children10020332] [PMID]

[21] Page MJ, Moher D. Evaluations of the uptake and impact of the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) Statement and extensions: A scoping review. Systematic Reviews. 2017; 6(1):263. [DOI:10.1186/s13643-017-0663-8] [PMID]

[22] Addison AB, Wong B, Ahmed T, Macchi A, Konstantinidis I, Huart C, et al. Clinical Olfactory Working Group consensus statement on the treatment of postinfectious olfactory dysfunction. The Journal of Allergy and Clinical Immunology. 2021; 147(5):1704-19. [DOI:10.1016/j.jaci.2020.12.641] [PMID]

[23] Alagesan J, Shetty A. Effect of modified suit therapy in spastic diplegic cerebral palsy-a single blinded randomized controlled trial. Online Journal of Health and Allied Sciences. 2011; 9(4):1-3. [Link]

[24] Taylor NF, Dodd KJ, Baker RJ, Willoughby K, Thomason P, Graham HK. Progressive resistance training and mobility-related function in young people with cerebral palsy: A randomized controlled trial. Developmental Medicine and Child Neurology. 2013; 55(9):806-12. [DOI:10.1111/dmcn.12190] [PMID]

[25] Bhalara A, Talsaniya D. Short term effect of myofascial release on calf muscle spasticity in spastic cerebral palsy patients. International Journal of Health Sciences and Research. 2014; 4(9):188-94. [Link]

[26] Ibrahim MM, Eid MA, Moawd SA. Effect of whole-body vibration on muscle strength, spasticity, and motor performance in spastic diplegic cerebral palsy children. Egyptian Journal of Medical Human Genetics. 2014; 15(2):173-9. [DOI:10.1016/j.ejmhg.2014.02.007]

[27] Emara HA, El-Gohary TM, Al-Johany AA. Effect of body-weight suspension training versus treadmill training on gross motor abilities of children with spastic diplegic cerebral palsy. European Journal of Physical and Rehabilitation Medicine. 2016; 52(3):356-63. [PMID]

[28] Hyun C, Kim K, Lee S, Ko N, Lee IS, Koh SE. The short-term effects of hippotherapy and therapeutic horseback riding on spasticity in children with cerebral palsy: A meta-analysis. Pediatric Physical Therapy. 2022; 34(2):172-8. [DOI:10.1097/PEP.0000000000000880] [PMID]

[29] Lai CJ, Liu WY, Yang TF, Chen CL, Wu CY, Chan RC. Pediatric aquatic therapy on motor function and enjoyment in children diagnosed with cerebral palsy of various motor severities.Journal of Child Neurology. 2015; 30(2):200-8. [DOI:10.1177/0883073814535491] [PMID]

[30] Jeong YA, Lee BH. Effect of action observation training on spasticity, gross motor function, and balance in children with diplegia cerebral palsy. Children. 2020; 7(6):64. [DOI:10.3390/children7060064] [PMID]

[31] Mattern-Baxter K, Looper J, Zhou C, Bjornson K. Low-intensity vs high-intensity home-based treadmill training and walking attainment in young children with spastic diplegic cerebral palsy. Archives of Physical Medicine and Rehabilitation. 2020; 101(2):204-12. [DOI:10.1016/j.apmr.2019.09.015] [PMID]

[32] Jha KK, Karunanithi GB, Sahana A, Karthikbabu S. Randomised trial of virtual reality gaming and physiotherapy on balance, gross motor performance and daily functions among children with bilateral spastic cerebral palsy. Somatosensory & Motor Research. 2021; 38(2):117-26. [DOI:10.1080/08990220.2021.1876016] [PMID]

[33] Babar SS, Zafar M, Ayub G, Ahmad I, Jabbar W. The effect of rood's ontogenic motor patterns on trunk control and balance in spastic diplegic cerebral palsy children: Effects of ROMP on trunk control and balance in CP. Journal of Health and Rehabilitation Research. 2024; 4(3):1-5. [DOI:10.61919/jhrr.v4i3.1562]

[34] Abushameh RSR, Topcu ZG, Tunal AN, Amro A, Al Arab A. The effects of ankle mulligan mobilisation in children with cerebral palsy: A randomized single blind control study. JPMA The Journal of the Pakistan Medical Association. 2024; 74(7):1-5. [Link]

[35] Chandler J, Churchill R, Higgins J, Lasserson T, Tovey D. Methodological standards for the conduct of new cochrane intervention reviews. Methodological Expectations of Cochrane Intervention Reviews. 2013; 3(2):1-14. [Link]

[36] Higgins JP, Altman DG, Gøtzsche PC, Jüni P, Moher D, Oxman AD, et al. The cochrane collaboration's tool for assessing risk of bias in randomised trials. BMJ. 2011; 343:d5928. [DOI:10.1136/bmj.d5928] [PMID]

[37] Makaracı Y, Soslu R, Özer Ö, Uysal A. Center of pressure-based postural sway differences on parallel and single leg stance in Olympic deaf basketball and volleyball players. Journal of Exercise Rehabilitation. 2021; 17(6):418-27. [DOI:10.12965/jer.2142558.279] [PMID]

[38] Bingöl H, Yılmaz Ö. Effects of functional massage on spasticity and motor functions in children with cerebral palsy: A randomized controlled study. Journal of Exercise Therapy and Rehabilitation. 2018; 5(3):135-42. [Link]

[39] Mahmood Q, Habibullah S, Babur MN. Potential effects of traditional massage on spasticity and gross motor function in children with spastic cerebral palsy: A randomized controlled trial. Pakistan journal of medical sciences. 2019; 35(5):1210. [DOI:10.12669/pjms.35.5.478]

[40] Kwon JY, Chang HJ, Yi SH, Lee JY, Shin HY, Kim YH. Effect of hippotherapy on gross motor function in children with cerebral palsy: A randomized controlled trial. Journal of Alternative and Complementary Medicine. 2015; 21(1):15-21. [DOI:10.1089/acm.2014.0021] [PMID]

[41] Goswami JN, Sankhyan N, Singhi P. Add-on home-centered activity-based therapy vs conventional physiotherapy in improving walking ability at 6-months in children with diplegic cerebral palsy: A randomized controlled trial. Indian Pediatrics. 2021; 58(9):826-32. [DOI:10.1007/s13312-021-2301-8] [PMID]

[42] Katusic A, Alimovic S, Mejaski-Bosnjak V. The effect of vibration therapy on spasticity and motor function in children with cerebral palsy: A randomized controlled trial. NeuroRehabilitation. 2013; 32(1):1-8. [DOI:10.3233/NRE-130817] [PMID]

[43] Deutz U, Heussen N, Weigt-Usinger K, Leiz S, Raabe C, Polster T, et al. Impact of hippotherapy on gross motor function and quality of life in children with bilateral cerebral palsy: A randomized open-label crossover study. Neuropediatrics. 2018; 49(3):185-92. [DOI:10.1055/s-0038-1635121] [PMID]

[44] Gurusamy L, Balaji G, Agrahara S. A multicenter, double blind, randomized controlled trial of functional strength training on gross motor function among children with spastic diplegic cerebral palsy. Physiotherapy Quarterly. 2022; 30(4):52-8. DOI: [DOI:10.5114/pq.2022.121156]

[45] Rasool F, Memon AR, Kiyani MM, Sajjad AG. The effect of deep cross friction massage on spasticity of children with cerebral palsy: A double-blind randomised controlled trial. Journal of the Pakistan Medical Association. 2017; 67(1):87-91. [Link]

[46] Liang X, Tan Z, Yun G, Cao J, Wang J, Liu Q, et al. Effectiveness of exercise interventions for children with cerebral palsy: A systematic review and meta-analysis of randomized controlled trials. Journal of Rehabilitation Medicine. 2021; 53(4):jrm00176. [DOI:10.2340/16501977-2772] [PMID]

[47] McIntyre S, Goldsmith S, Webb A, Ehlinger V, Hollung SJ, McConnell K, et al. Global prevalence of cerebral palsy: A systematic analysis. Developmental Medicine and Child Neurology. 2022; 64(12):1494-506. [DOI:10.1111/dmcn.15346] [PMID]

[48] Yang G, Su H, Yang M, Chang J. The effect of physical exercise on gross motor function in children with cerebral palsy: a Meta-analysis. International Journal of Human Movement and Sports Sciences. 2022; 10:581-91. [DOI:10.13189/saj.2022.100327]

[49] Salazar AP, Pagnussat AS, Pereira GA, Scopel G, Lukrafka JL. Neuromuscular electrical stimulation to improve gross motor function in children with cerebral palsy: A meta-analysis. Brazilian Journal of Physical Therapy. 2019; 23(5):378-86. [DOI:10.1016/j.bjpt.2019.01.006] [PMID]

[50] Muazarroh S, Kristiyanto A, Prasetya H. Meta-analysis effectiveness of massage on spasticity in children with cerebral palsy. Indonesian Journal of Medicine. 2022; 7(2):209-18. [DOI:10.26911/theijmed.2022.07.02.09]