Review Article

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

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Running title: Effects of Physical Therapy in Cerebral Palsy

Abstract
Background: Cerebral Palsy is the one of leading cause of disability among pediatric population, especially in Asia. Permanent disability is mostly due to the spasticity and poor gross motor function, adding significant socioeconomic burden on healthcare system. This study evaluate the effectiveness of Physical Therapy based interventions on improving Gross Motor Function and reducing Spasticity.
Material and Methods: A thorough search on CINAHL, PubMed, PEDro, Web of Science, and Scopus from February to July 2024 for studies assessing spasticity by Modified Ashworth Scale and gross motor function by 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 $p < 0.0001$ (CI 95%= (0.20. 0.50), 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, as measured by the GMFM-88. However, there was no overall significant impact on all dimensions of GMFM-88 p = 0.5821 (CI 95%= (-0.0508. 0.301), SMD= 0.125, Q=6.5843). Additionally, interventions targeting spasticity reduction showed no significant effects p = 0.1018 (CI 95%= (0.20. 0.50), SMD= 0.306, Q=10.5922) according to the Modified Ashworth scale.

Conclusion: This meta-analysis reveals that modified suit therapy, vibration therapy, and hippotherapy enhance standing and walking in the 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 cerebral palsy.

Keywords: Diplegic Cerebral Palsy, Spasticity, Hippotherapy, Myofascial release, Gross Motor Function

Introduction

Globally, 0.9% of people have cerebral palsy. [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 (NSCH) and the National Health Interview Survey (NHIS), the prevalence in the United States was estimated to be 2.6 per 1000 [3] While the prevalence rate of cerebral palsy in Europe was approximately 0.8 per 10000 live birth that shows the high difference in various regions. [51] Regarding the prevalence of cerebral palsy in Pakistan, cerebral palsy is the third most common neurological condition in the child population accounting for 10.5% of cases while epilepsy is the most common neurological condition affecting 36% of children [4], with a significantly higher frequency of 1.22 per 1000 live births [5]. Spastic diplegic and spastic quadriplegic cerebral palsy are the most common subtypes of cerebral palsy in Pakistan making up 39% of cases. In comparison, athetoid (3.34%) and ataxic (10.1%) cerebral palsy are the next most common subtypes [6].

Individuals with spastic diplegic cerebral palsy exhibit distinct characteristics, including increased muscle tone, scissoring of the lower extremities, and functional impairment. Scissors in the lower limbs, a common manifestation in spastic diplegic cerebral palsy, often result from hamstring and gastrocnemius hypertonia [7]. 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 [8]. However, the spasticity in the lower extremities leads to difficulty in ambulation and directly affects the gross motor function of children with spastic diplegic cerebral [9,10]. Fortunately, spastic diplegic cerebral palsy can be managed with various pharmacological and non-pharmacological approaches [11].

Pharmacological management includes the use of oral baclofen and botulinum toxin injections. [11]Surgical interventions such as intrathecal baclofen and muscle lengthening procedures are also used to reduce spasticity [11,12]. Although the intervention showed some adverse effects including increasing spasticity, stomach discomfort, etc [13]. However, physical therapy plays a vital role in the management of spastic diplegic cerebral palsy. It is critical to improving outcomes for affected individuals. Various physical therapy approaches have been used effectively, including neurodevelopmental therapies [14], strengthening,[15] passive stretching [16], strength training combined with stretching [17], restriction-induced movement therapy, and targeted motor reduction programs.[18] However, a comprehensive meta-analysis was conducted in 2022 among twenty-seven RCTs with 847 participants and demonstrated that the strengthening of lower extremities has a positive impact on functional capabilities and gross motor function exacerbating the spasticity among children with spastic diplegic cerebral palsy.[19] Spasticity is a crucial component among the cerebral palsy population, to find a relevant intervention for the reduction of spasticity a recent meta-analysis conducted among only three RCTs shows extracorporeal shockwave therapy is significantly reducing spasticity [20].

Even though there are many randomized controlled trials on various therapies available, there remains a lack of comprehensive reviews on interventions for the reduction of spasticity and enhancement of gross motor function among individuals with cerebral palsy. This meta-analysis aims to address this gap by synthesizing an extensive review of various physical therapy interventions to decrease spasticity and enhance gross motor function.

Methodology

Protocol Registration:

This meta-analysis fulfilled the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) requirements [21] and was also documented in the global PROSPERO database (registration number: CRD42024535904).

Inclusion criteria:

The inclusion criteria for this meta-analysis were based on the Population, Intervention, Outcome, and Design (PIOD) methodology [22].

Population:

Participants in the studies varied in age from 1 to 22 years and had diplegic cerebral palsy.

Intervention:

Physical therapy interventions—such as modified suit therapy [22], progressive resistance training[23], myofascial release[24], whole body vibration[25], body weight suspension training[26], hippo therapy[27], pediatric aquatic therapy[28], action observation training[29], low- and high-intensity treadmill training[30], virtual reality games[31], Rood approach [32], Mobilization [33] and functional strength training[34] were included in this meta-analysis.

Outcome:

Gross Motor Function Measure-88 (GMFM-88), GMFM-88 Dimension D for standing and Dimension E for walking, and Modified Ashworth scale (MAS).

Design:

The study only comprised randomized controlled trials.

Exclusion criteria:

Studies involving cerebral palsy patients receiving therapies other than physical therapy or lacking a control group were not included in the analysis. Additionally, the meta-analysis only included research that were published in English or had translations accessible; papers published before to 2011 were excluded.

Data extraction and search strategy:

A thorough search approach was carried out by two separate researchers in multiple databases, including CINAHL, PubMed, PEDro, Web of Science, and Scopus, between February 2024 to 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 "Cerebral palsy" OR "CP" AND "Spasticity" AND "Gross Motor Function" OR "GMFM" AND "Motor symptoms" OR "Standing" AND "Walking Abilities"

Risk of bias of assessment:

Various methods are 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 [35].

Data analysis:

To analyze the data, MedCalc 18.11.3 Statistical Software was used. 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 both the physiotherapy treatment and control groups. Both the fixed effects and random effects models were used to assess the pooled effect size estimations. The Modified Ashworth scale, GMFM-88, and GMFM-88 (Dimension D for standing & Dimension E for walking) scores were analyzed using the mean, standard deviation, and 95% confidence intervals for both the experimental and control groups.

Heterogeneity was quantified using the I^2 statistic, with values ranging from 0% to 100% signifying the degree of heterogeneity. According to the I2 values, there is 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%. [**Error! Reference source not found.**]For modest to moderate heterogeneity, a fixed-effects model was employed; for considerable to high heterogeneity, a random-effects model was used. 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), and large (0.8 or above). [36]

Results

A comprehensive search on electronic databases such as CINAHL, PubMed, PEDro Web of Science, and Scopus, found a total number of 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)

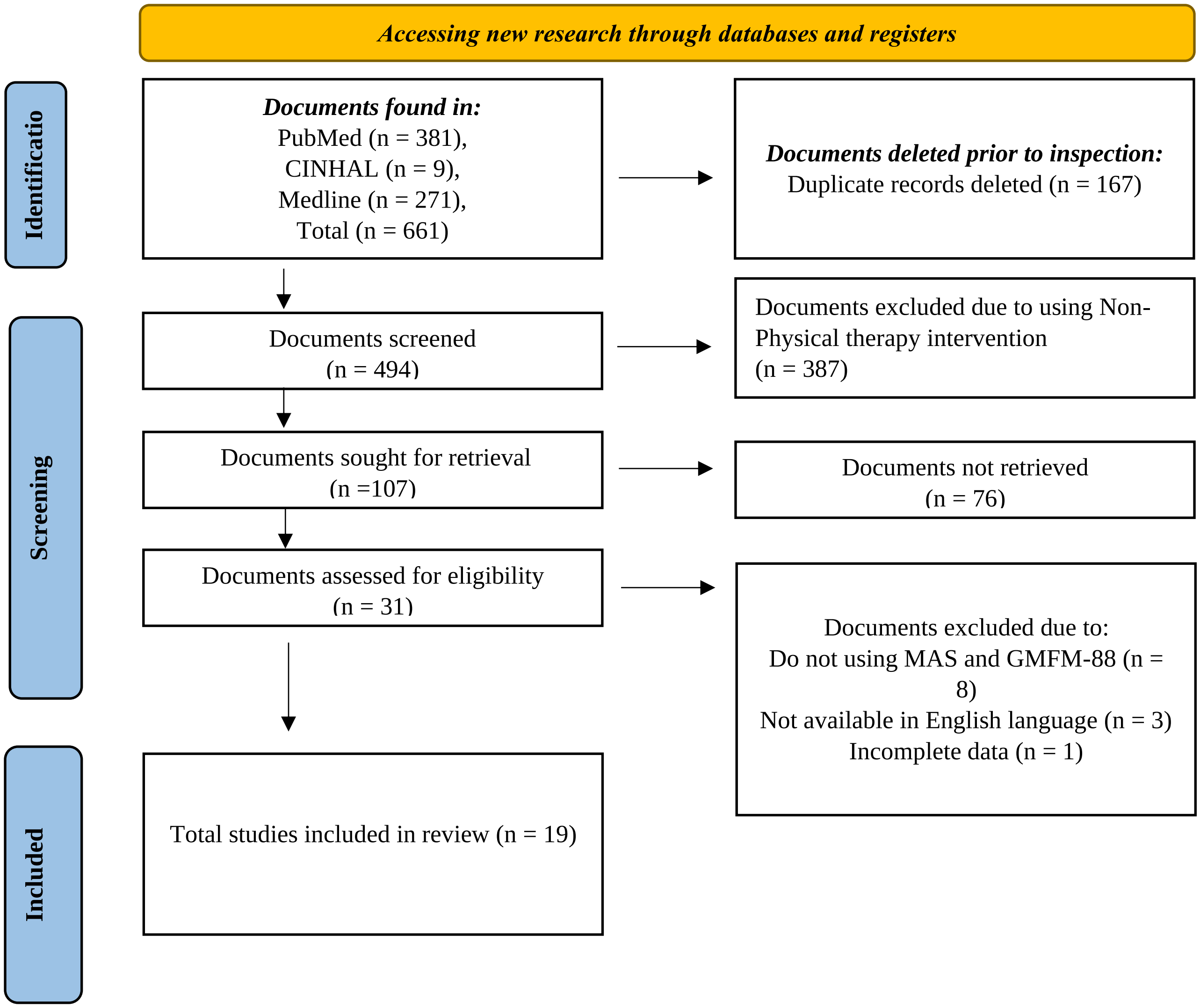

Figure 1: PRISMA flowchart for study selection

Table 1 summarizes the characteristics and findings of 19 studies included in this review, all of which employed a randomized controlled trial (RCT) design to investigate interventions for diplegic cerebral palsy. The sample sizes varied across studies, with both experimental (EG) and control groups (CG) ranging from 9 to 45 participants, targeting a population of children and adolescents with diplegic CP. The age range of participants spanned from 1 to 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 Roods ontogenic motor pattern, and Grade III sustained posteroanterior glide to tibia while talus and calcaneus are fixed. The control groups typically received conventional physical therapy. The Gross Motor Function Measure (GMFM-88) was a commonly used outcome measure, along with its dimensions D & E, and the Modified Ashworth Scale (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 cerebral palsy. However, some studies found minimal or no significant effects for progressive resistance training, body-weight suspension training and virtual reality games and home-centered activity-based therapy.

Table 1. Characteristics of the included research

Author' Year	Study Design	Sample Size	Target Population	Age	Intervention Group	Control Group	Outcome measures	Result
Alagesan et al., 2011	RCT	EG (15) CG (15)	Diplegic CP	4-12 years	Modified Suit therapy along with conventional therapy with 21 sessions of 2 hours each with 20 minutes of short break for 3 weeks.	Conventional therapy with 21 sessions of 2 hours each with 20 minutes of short breaks for 3 weeks.	GMFM-88	Children with spastic diplegic cerebral palsy can benefit from a combination of modified suit therapy and conventional physiotherapy to enhance their gross motor function.
Katusic et al., 2013	RCT	EG (45) CG (44)	Diplegic CP	4-6 years	Sound-based vibration treatment along with conventional physical therapy throughout the course of 12 weeks, with 36 sessions lasting 40 minutes each.	Conventional physical therapy throughout the course of 12 weeks, with 36 sessions lasting 40 minutes each.	GMFM-88	Vibration treatment combined with regular physical therapy led to significant improvements in gross motor function.
Taylor et al., 2013	RCT	EG (23) CG (25)	Diplegic CP	14-22 years	Progressive resistance training with 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 reveals that progressive resistance training shows minimal variation in the walking and standing abilities among children with diplegic cerebral palsy

Bhalara et al., 2014	RCT	EG (9) CG (9)	Diplegic CP	2-8 years	Myofascial release along with stretching with 24 sessions lasting 30 minutes each over the 4 weeks.	Stretching with 24 sessions lasting 30 minutes each over 4 weeks.	MAS	Stretching combine with myofascial release reduce spasticity more effectively than stretching alone.
Ibrahim et al., 2014	RCT	EG (15) CG (15)	Diplegic CP	8-12 years	Whole body vibration treatment throughout the course of 12 weeks, with 36 sessions lasting 40 minutes each.	Conventional physical therapy throughout the course of 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	RCT	EG (11) CG (13)	Diplegic CP	4-12 years	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 was unable to determine how paediatric aquatic therapy affected the treatment of spasticity.
Kwon et al., 2015	RCT	EG (45) CG (46)	Diplegic CP	4-10 years	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 cerebral palsy, hippotherapy improves gross motor ability.
Emara et al., 2016	RCT	EG (10) CG (10)	Diplegic CP	6-8 years	Body-weight suspension training along with conventional physical therapy throughout the course of 12 weeks, with 36 sessions lasting 40 minutes each.	Treadmill training along with conventional physical therapy throughout the course of 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.
Rasool et al., 2017	Double-blinde	EG (30) CG (30)	Diplegic CP	6-8 years	Cross friction massage along with conventional physical therapy	Conventional physical therapy throughout the course of six	MAS	Deep cross-friction massage is a useful

	d RCT				throughout the course of six weeks, in thirty sessions of thirty minutes each.	weeks, in thirty sessions of thirty minutes each.		therapeutic approach for controlling spasticity in children with dipelgic cerebr al palsy.
Bingol et al., 2018	RCT	EG (10) CG (10)	Diplegic CP	5-12 years	Functional massage was given in 16 session with 45-minute each spread 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 reducing spasticity and increasing some motor function parameters in children with diplegic CP can be achieved with the use of Functional Massage in conjunction with Traditional Physiotherapy.
Lucena et al., 2018	RCT	EG (22) CG (22)	Diplegic CP	3-14 years	Along with traditional treatment in 12 weeks of 12 sessions, each lasting 45 minutes, including equestrian hippo-therapy.	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 cerebr al palsy induces statistically significant reductions in hip adductor spasticity.
Mahmood et al., 2019	RCT	EG (38) CG (37)	Diplegic CP	2-10 years	Traditional massage along with conventional physical therapy with 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 cerebr al palsy who are experiencing spasticity;

								however, it is best when paired with conventional physical therapy (CPT) to enhance gross motor function.
Jeong et al., 2020	RCT	EG (9) CG (9)	Diplegic CP	5-11 years	Action Observation Training: 6 weeks of 18 sessions, each lasting 30 minutes.	Conventional physical therapy: 6 weeks of 18 sessions, each lasting 30 minutes.	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 cerebral palsy who have spastic diplegia.
Mattern et al., 2020	RCT	EG (10) CG (9)	Diplegic CP	1-3 years	Low-intensity treadmill training with 12 sessions lasting 20 minutes each over the 6 weeks.	High-intensity treadmill training with 12 sessions lasting 20 minutes each over the 6 weeks.	GMFM-88 (D & E)	According to the study, children in the high intensity group had comparable skills at follow-up assessments, although their improvements in GMFM E scores were comparatively less than those of the low intensity group immediately after the intervention.
Jha et al., 2021	RCT	EG (19) CG (19)	Diplegic CP	6-12 years	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 cerebral palsy, 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	RCT	EG (30) CG (29)	Diplegic CP	5-12 years	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 a 6-month period, no apparent gains in gross motor function were seen.
Gurusamy et al., 2022	RCT	EG (30) CG (29)	Diplegic CP	5-12 years	Functional strength training 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 cerebral palsy, functional strength training enhanced standing and walking abilities.
Babar et al., et al 2024	RCT	EG (11) CG (11)	Diplegic CP	3-10 years	Functional Electrical stimulation combined with Roods 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 Roods ontogenic motor pattern enhanced motor functions.
Abushameh et al., 2024	RCT	EG (32) CG (32)	Diplegic CP	4-12 years	Grade III sustained posteroanterior glide to tibia while talus and	Conventional physical therapy spread over 4 weeks, with	GMFM-88	The study found that the mobilization had greater impact on

		calcaneus are fixed spread over 4 weeks, with twelve 40-45 minutes session.	twelve 40-45 minutes session.		gross motor function.

Abbreviation: RCT; Randomized control Trial, EG; Experimental Group, CP; Cerebral palsy, CG; Control Group, MAS; Modified Ashworth Scale, GMFM; Gross Motor Function Measure

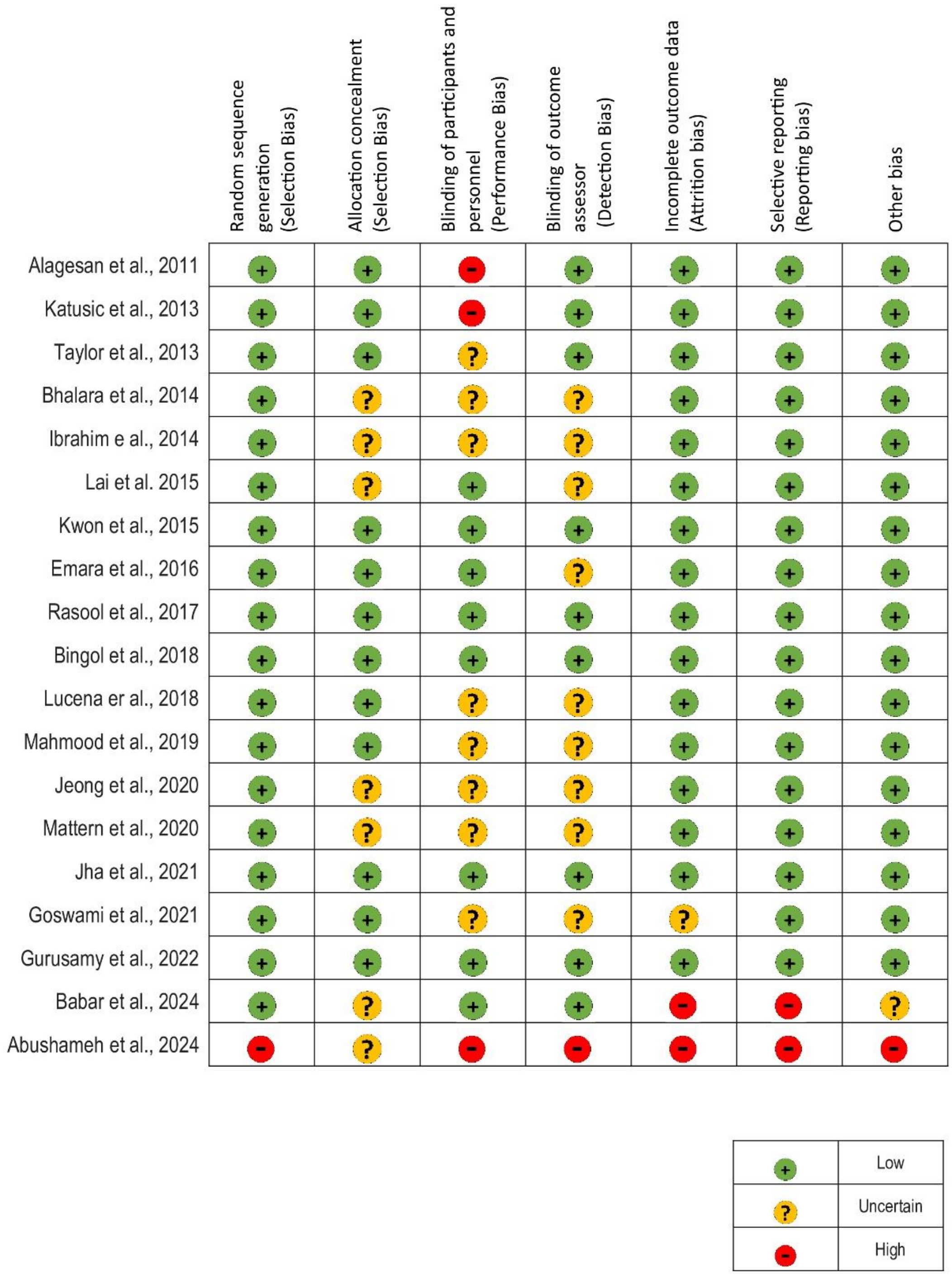

Figure 2: Risk of Bias of MAS and GMFM-88.

GMFM-88

Nine studies that examine the gross motor function among individuals with cerebral palsy were added. All of the studies focus on all the dimensions of GMFM-88including lying, sitting, rolling, standing, and walking. [22,31,32,33,36,37,39,40,41] 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 (CI 95%= (-0.0508. 0.301), SMD= 0.125). The studies show low heterogeneity (Q=6.5843, I2=0.00%), which indicates the consistency in the effect size across the studies. Additionally, no substantial publication bias was identified (p=0.5181). (Table 2 and Figure 3)

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

Study	N1	N2	Total	SMD	SE	95% CI	t	P	Weight (%)	
									Fixed	Random
Alagesan et al., 2011	15	15	30	0.815	0.371	0.0558 to 1.574			5.85	5.85
Katusic et al., 2013	45	44	89	0.121	0.210	-0.297 to 0.539			18.14	18.14
Kwon et al., 2015	45	46	91	0.0223	0.208	-0.391 to 0.435			18.57	18.57
Bingol et al., 2018	10	10	20	-0.228	0.430	-1.131 to 0.675			4.35	4.35
Mahmood et al., 2019	38	37	75	0.00258	0.229	-0.453 to 0.458			15.36	15.36
Jha et al., 2021	19	19	38	0.371	0.320	-0.279 to 1.021			7.82	7.82
Goswami et al., 2021	30	29	59	-0.0886	0.257	-0.603 to 0.426			12.14	12.14
Babar et al., 2024	11	11	22	0.0390	0.410	-0.817 to 0.895			4.77	4.77
Abushameh et al., 2024	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									
Significance level	P = 0.5821									
I^2 (inconsistency)	0.00%									

95% CI for I^2	0.00 to 57.54
Egger's Test	
Intercept	1.3805
95% CI	-2.6551 to 5.4161
Significance level	P = 0.4195

GMFM: Gross Motor Function Measure

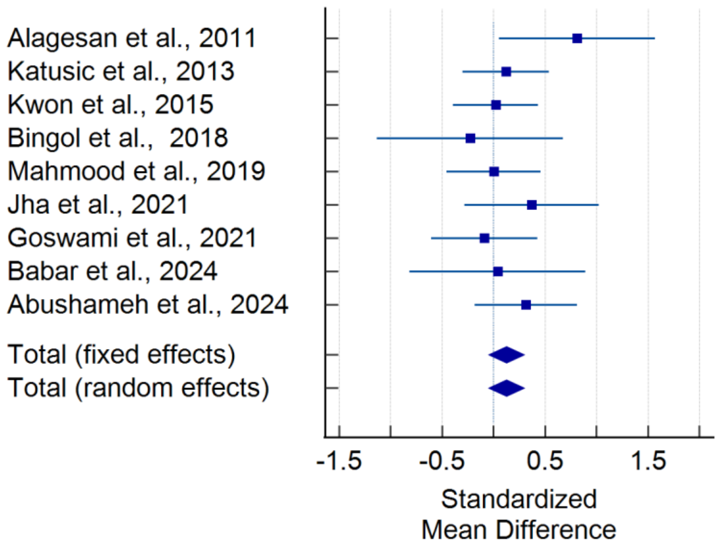

Figure 3: Forest plot to illustrate the GMFM-88

GMFM-88 (D & E)

The remaining six studies solely focused on cerebral palsy individual's walking and standing abilities. [23,26,29,30,42,43] 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 (CI 95%= (0.20. 0.50), SMD= 0.563) (Table 3 and Figure 4) and minor but significant improvement ($p=0.004$) in standing ability (CI 95%= (0.20. 0.50), SMD= 0.187) (Table 4 and Figure 5). However, there was high heterogeneity for standing (Q=22.5239, I2=77.80%) as well as the walking ability (Q=43.9325, I2=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 any signs of publication bias.

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

Study	N1	N2	Total	SMD	SE	95% CI	t	P	Weight (%)	
									Fixed	Random
Taylor et al., 2013	23	24	47	0.252	0.288	-0.328 to 0.833			30.72	17.93

Ibrahim e al., 2014	15	15	30	3.452	0.570	2.285 to 4.620			7.85	15.18
Emara et al., 2016	10	10	20	-1.259	0.472	-2.252 to -0.267			11.43	16.23
Jeong et al., 2020	9	9	18	0.0333	0.449	-0.918 to 0.985			12.65	16.47
Mattern et al., 2020	9	10	19	0.253	0.441	-0.677 to 1.183			13.12	16.55
Gurusamy et al., 2022	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									
Significance level	P < 0.0001									
I2 (inconsistency)	88.62%									
95% CI for I2	77.80 to 94.17									
Egger's Test										
Intercept	2.6276									
95% CI	-13.1424 to 18.3977									
Significance level	P = 0.6677									

GMFM: Gross Motor Function Measure

Table 4: Random-effects analysis of GMFM-88 Standing dimension

Study	N1	N2	Total	SMD	SE	95% CI	t	P	Weight (%)	
									Fixed	Random
Taylor et al., 2013	23	24	47	0.373	0.289	-0.210 to 0.956			28.10	18.79
Ibrahim e al., 2014	15	15	30	1.105	0.383	0.321 to 1.889			16.06	17.00
Emara et al., 2016	10	10	20	-1.784	0.513	-2.862 to -0.707			8.95	14.45
Jeong et al., 2020	9	9	18	0.0763	0.449	-0.876 to 1.028			11.67	15.69
Mattern et al., 2020	9	10	19	0.340	0.442	-0.593 to 1.274			12.03	15.82
Gurusamy et al., 2022	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									
Significance level	P = 0.0004									
I2 (inconsistency)	77.80%									
95% CI for I2	50.85 to 89.97									
Egger's Test										
Intercept	-5.7838									

95% CI	-16.5851 to 5.0174
Significance level	P = 0.2113

GMFM: Gross Motor Function Measure

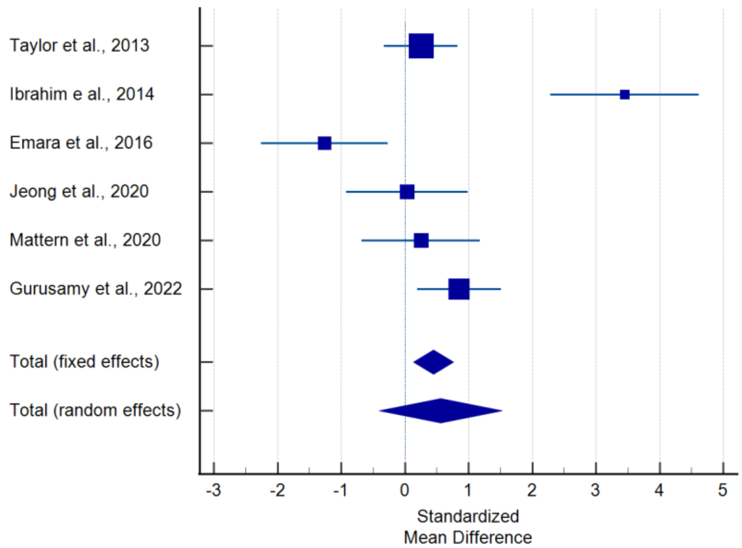

Figure 3: Forest plot to illustrate the GMFM-88 (Dimension E for walking)

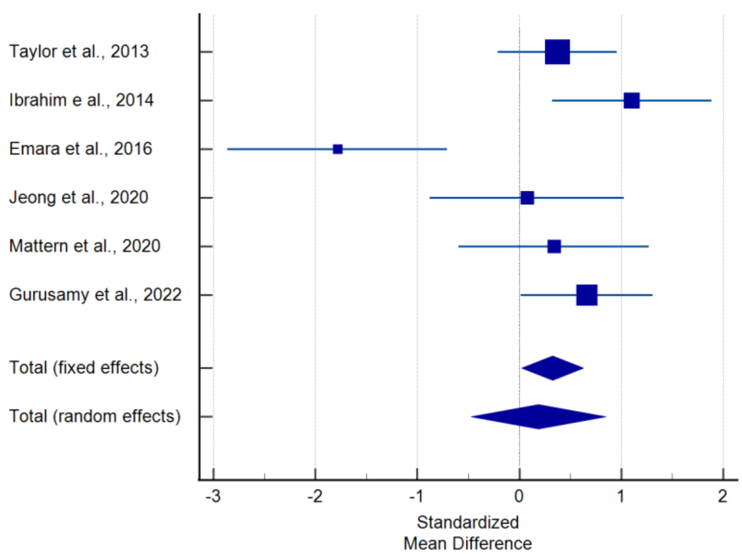

Figure 4: Forest plot to illustrate the GMFM-88 (Dimension D

Spasticity
Furthermore, seven studies focused on spasticity assessment using the MAS in individuals with cerebral palsy. [2,24,25,28,37,38,44] The meta-analysis revealed a reduction in spasticity was not statistically significant (p=0.1018) associated with interventions such as function massage, traditional massage, myofascial release, whole body vibration, pediatric aquatic therapy, cross-friction massage, and equestrian therapy (CI 95%= (0.20. 0.50), SMD= 0.306) (Table 4 and Figure 5). Moderate heterogeneity was found among the studies, (Q=10.5922, I2=43.35%), indicating some variability in the effect size, but no significant publication bias was detected (p=0.1700). (Table 5 and Figure 6)

Table 5: Random-effects model results for Modified Ashworth Scale

Study	N1	N2	Total	SMD	SE	95% CI	t	P	Weight (%)	
									Fixed	Random
Bhalara et al., 2014	9	9	18	-0.358	0.453	-1.318 to 0.602			7.15	9.71
Ibrahim e al., 2014	15	15	30	-0.354	0.358	-1.088 to 0.380			11.43	13.26
Lai et al. 2015	11	13	24	0.564	0.404	-0.274 to 1.401			8.99	11.38
Rasool et al., 2017	30	30	60	-0.841	0.266	-1.374 to -0.309			20.70	18.25
Bingol et al., 2018	10	10	20	-0.160	0.429	-1.061 to 0.742			7.97	10.48
Lucena er al., 2018	22	22	44	-0.0345	0.296	-0.632 to 0.563			16.73	16.44
Mahmood et al., 2019	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									
Significance level	P = 0.1018									
I2 (inconsistency)	43.35%									
95% CI for I2	0.00 to 76.18									
Egger's Test										
Intercept	3.0465									
95% CI	-1.8412 to 7.9343									
Significance level	P = 0.1700									

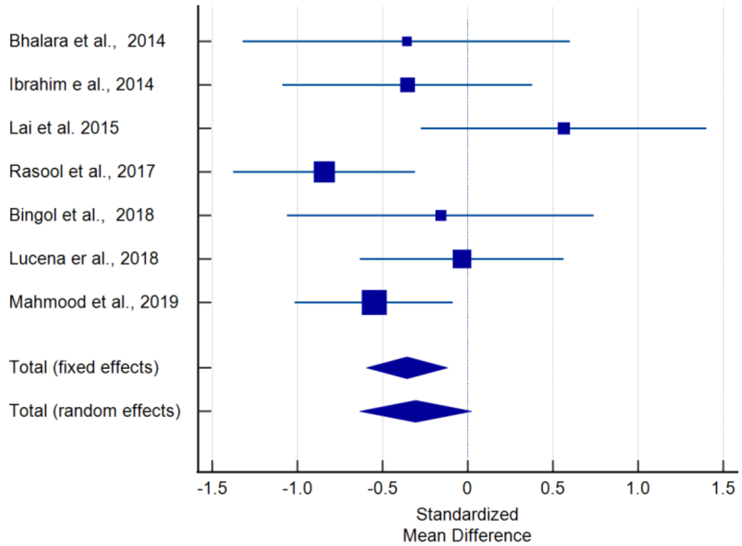

Figure 5: Forest Plot to illustrate the Modified Ashworth Scale (MAS).

The Risk of Bias

The assessment of risk of bias for the included articles 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 has high risk. Allocation concealment was reported in 12 studies, while it was unclear in 7 studies, and high risk was not identified in any study. Blinding of the participants and personnel was performed in 8 studies, with 8 studies rated as unclear and 3 studies at high risk. Incomplete outcome data were assessed as low risk in 16 studies and unclear in 1 study, with 2 studies rated as high risk. In 17 trials, the risk of selective reporting was determined to be low while 1 is unclear and 1 has low risk. Moreover, 17 investigations disclosed no additional biases, 1 has unclear and 1 has low risk. These findings indicate 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, leading to the inclusion of 17 studies after removing duplicated and irrelevant ones. The primary objective was to evaluate how different methods or treatment strategies can affect the gross motor function that is 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 games. The studies showed low heterogeneity, suggesting a consistency in the effect size across them. [22,31,32,33,36,37,39,40,41]

In the studies that focus on dimension D for the standing ability, the intervention resulted in a statistically significant improvement (p=0.0004), indicating significant variation in the effect size across the studies. [23,26,29,30,42,43]

Similarly, in studies that examine dimension E for walking ability, the intervention led to a statistically significant improvement ($p<0.0001$) with very high heterogeneity. [23,26,29,30,42,43] These findings are in line with studies such as Yang et al.'s investigation, which also found significant improvement in the walking and standing abilities but not in the lying, sitting, and rolling abilities. [48]This underscores the need for tailored approaches to address specific motor skill deficits in children with cerebral palsy. Furthermore, Liang et al examined the effects of multiple physical therapy exercises on all dimensions of GMFM-88 and reported no significant improvement in it.[45]The meta-analysis conducted to show the effects of neuromuscular electrical stimulation on gross motor function by Salazar et al reported that neuromuscular stimulation 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 ($p=0.1018$) in spasticity with interventions like functional massage, traditional massage, myofascial release, whole-body vibration, pediatric aquatic therapy, cross-friction massage, and equestrian therapy. Although there was moderate heterogeneity among studies, an indication of some variability in the effect size.

Compared to earlier meta-analyses, such as the one by Muazarroh et al., which discovered that massage was proved to help reduce the hypertonicity of muscle in individuals with cerebral palsy [50]. While Hyen et al., conducted a study demonstrating the benefits of therapeutic horseback riding and hippotherapy on spasticity in the short term. Nevertheless, there was no apparent distinction between single trials and repeated sessions. [27]

The assessment of risk of bias for the included articles in the meta-analysis revealed several key findings. Randomization occurred in all 7 studies, indicating a strong methodological approach to participant allocation. Allocation concealment was reported in 12 studies, while it was unclear in 5 studies, and high risk was not identified in any study. Blinding of the participants and personnel was performed in 7 studies, with 8 studies rated as unclear and 2 studies at high risk. Incomplete outcome data were assessed as low risk in 16 studies and unclear in 1 study, with no studies rated as high risk. In all 17 trials, the risk of selective reporting was determined to be low. Moreover, none of the 17 investigations disclosed any additional biases. These findings indicate a minimal risk of bias across most domains, indicating a high level of evidence in this meta-analysis. (Figure 2)

This study offers important information about the effects of different interventions to improve gross motor skills and lower the hypertonicity of muscles inindividuals with cerebral palsy. It also complies with PRISMA guidelines and assesses the possibilities 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 cerebral palsy and offers additional proof of the effectiveness of these therapies.

Recommendations

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

Limitations

When analyzing the outcome, it is important to take into account some constraints. Functional outcomes and quality of life are significant factors in treatment planning, but the study did not assess the effects of any particular intervention on these variables. Furthermore, the study did not take into consideration confounding factors that can affect the results, including comorbidities or concomitant medications.

Conclusion

The influence of various therapies on the gross motor skills and spasticity of individuals with cerebral palsy is comprehensively examined in this meta-analysis's. It 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 cerebral palsy. These outcomes confirm the effectiveness of these therapies and highlight the need for specialized approaches to the management of cerebral palsy.

Author Contributions:

Conceptualization, [Hamza Ahmed, Muhammad Abid Khan];
Methodology, [Hamza Ahmed, Muhammad Abid Khan];
Investigation, [Muhammad Abid Khan, Fouzia Hussain];
Writing – Original Draft, [Meeran Hasnain, Dr. Raman Kumar];
Writing – Review & Editing, [Fouzia Hussain];
Supervision, [Muhammad Abid Khan, Fouzia Hussain]

Ethical Considerations

Compliance with ethical guidelines (Code Number)

There is no human or animal sample in this meta-analysis.

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Conflict of interest:

The authors declared no conflict of interest.

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