



The Effectiveness of Partial Body Weight Support on Walking in People with Cerebral Palsy: A Systematic Review



Xanthi Chrysoula ^a, Stamelaki Magdalini ^b, Dimitriadis Zacharias ^c, Paras Georgios ^d, Besios Thomas ^e

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Corresponding Author ^a



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cerebral palsy;
gait training;
partial body weight support;
physiotherapy;
walking;

Abstract

Background: People with Cerebral Palsy (CP) face daily motor, sensory, and cognitive impairments that significantly impact their quality of life. This systematic review aimed to investigate RCTs regarding the effectiveness of treadmill walking with partial body weight support (PBWSTT) in individuals with CP. Methods: A search was performed in PubMed, Scopus and Research Gate. The study selection process was conducted by two separate reviewers. The quality of the final studies included in the systematic review was assessed using the PEDro scale. Results: Out of the 673 studies initially identified, 6 studies were included. The results showed that (PBWSTT) leads to an increase in scores on the GMFM scale, as well as improvement in walking pattern, speed, endurance, and rhythm. The method of PBWSTT in comparison to conventional physiotherapy did not show better results, as the included studies in this review showed conflicting results. Conclusion: The effect of therapeutic exercise with partial body weight support has a positive impact on improving the gross motor function of patients with Cerebral Palsy. However, the question of whether PBWSTT is more effective than conventional physiotherapy and over-ground walking exercise cannot be conclusively answered yet, highlighting the importance of conducting further research in this field.

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- ^a Physical therapist, Department of Physical Therapy, University of Thessaly, Human Performance & Rehabilitation Laboratory, Lamia, Greece
^b Physical therapist, Department of Physical Therapy, University of Thessaly, Human Performance & Rehabilitation Laboratory, Lamia, Greece
^c Physical therapist, Associate Professor of the Department of Physiotherapy at the University of Thessaly, Lamia, Greece
^d Physical therapist, Assistant Professor, Department of Physical Therapy, University of Thessaly, Human Performance & Rehabilitation Laboratory, Lamia, Greece
^e Physical therapist, Assistant Professor, Department of Physical Therapy, University of Thessaly, Human Performance & Rehabilitation Laboratory, Lamia, Greece
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1 Introduction

Cerebral palsy arises from destructive processes that injure healthy brain tissue rather than abnormalities in brain development (Eunson, 2012; Richards & Malouin, 2013). Pathological and imaging studies of cerebral palsy have revealed various combinations of damage to the cerebral cortex, white matter, basal ganglia, and the brainstem (Graham et al., 2016). The stage of brain maturation during which pathogenic events occur defines the type and location of damage, as well as the specific response to injury. These disorders result from non-progressive interference, damage, or abnormality in the developing brain (Bax et al., 2005). There are four main types of cerebral palsy: spastic, dyskinetic, ataxic, and mixed type (Michael-Asalu et al., 2019).

The diagnosis of cerebral palsy is primarily based on motor dysfunction and postural disturbances that manifest in early childhood and persist throughout the individual's life. Functional impairments, often accompanied by other dysfunctions such as sensory and cognitive deficits, communication and behavioural disorders, epileptic episodes, and secondary musculoskeletal problems, constitute the core symptoms of cerebral palsy. According to the Surveillance of Cerebral Palsy in Europe (SCPE), the average frequency of cerebral palsy is estimated to be 2.08 per 1000 births for children with a birth weight above 2500 grams. However, for children born with a birth weight of less than 1500 grams, the incidence of cerebral palsy is 70 times higher (Sadowska et al., 2020).

Cerebral palsy and Partial Body Weight Supported Treadmill Training (PBWSTT)

Education on a treadmill is a dynamic approach to acquiring motor skills in individuals with cerebral palsy (CP) (Cherng et al., 2007; Dodd et al., 2007). Partial Body Weight Supported Treadmill Training (PBWSTT) is an active, repetitive, task-specific approach used to facilitate walking and movement, aiming to achieve a more natural walking pattern. Treadmill training is based on current theories of motor learning (Barbeau et al., 2003; Day et al., 2004).

PBWSTT helps therapists systematically train patients to walk on a treadmill at increasing speeds with a gradual reduction of partial body weight support, simulating what is necessary for home or community activities. During PBWSTT, a harness system supports the child's body weight while the therapist manually guides leg movements (Begnoche et al., 2007).

Therapists provide verbal and tactile cues to facilitate the kinematic, kinetic, and temporal characteristics of walking. It is reasonable to assume that treadmill sessions influence motor learning, strengthen leg muscles, activate the motor control system, and improve functional abilities as the child practices and experiences walking behaviour in various activities (Richards et al., 1997).

Although PBWSTT was initially developed to facilitate improved movement in ambulant individuals, non-ambulant walkers, including children with severe disabilities who may never experience walking in regular conditions, can also engage in motor movements on a slow-moving treadmill (Phillips et al., 2007).

Similar systematic reviews have reported that the evidence regarding functional outcomes of PBWSTT is limited and that statistical significance is not demonstrated in several studies, despite reported improvements in general motor function, functional status, walking performance, and gait parameters. They also cite the

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small number of available studies and the limited number of participants as primary limitations (Mutlu et al., 2009; Valentin-Gudiol et al., 2013; Alotaibi et al., 2023). This systematic review was conducted to explore more recent randomized controlled studies to attempt to clarify the effectiveness of walking on a treadmill with partial body weight support in individuals with cerebral (Walker et al., 2010; Schindl et al., 2000).

2 Materials and Methods

This systematic review was conducted according to the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (Page et al., 2021).

PROSPERO NUMBER: CRD42023466651

Eligibility criteria

The final inclusion of studies in the qualitative synthesis requires the establishment of specific inclusion and exclusion criteria. Thus, the inclusion criteria consisted of studies: a) Published between 2010-2023, b) Exclusively published in the English language, c) Randomized controlled trials, d) Samples diagnosed with Cerebral Palsy, e) Studies where the sample's walking ability is assessed with the respective reliable and valid tool, f) Studies that selected walking on a treadmill with partial body weight support as the intervention. On the other hand, exclusion criteria included: a) Pilot-type studies, and b) Studies using robotic devices, virtual reality, or functional electrical stimulation as an intervention in the experimental group or the control group.

Information sources, search strategy and selection process

A search of the databases PubMed, Scopus and Research Gate was performed on 01 October 2023. The databases used the additional restriction of 2010–2023 before displaying the keyword search results. The following keywords were used for the search: cerebral palsy, partial body weight support, gait training, and physiotherapy (Moucheboeuf et al., 2020; Shankaranarayana et al., 2021). The capture of the search strategies in the databases is given in Table 1.

The eligibility of the studies was assessed separately by two reviewers and there was the possibility of a third person to give his consent in case of disagreement, but this was not necessary as the first two were in full agreement with the final results of the qualitative synthesis of the studies.

Table 1
Capture of search strategies in the selected databases

Database	Capture of search strategy
PubMed	((("cerebral palsy"[MeSH Terms] OR ("cerebral"[All Fields] AND "palsy"[All Fields]) OR "cerebral palsy"[All Fields]) AND (("gait"[MeSH Terms] OR "gait"[All Fields]) AND ("education"[MeSH Subheading] OR "education"[All Fields] OR "training"[All Fields] OR "education"[MeSH Terms] OR "train"[All Fields] OR "train s"[All Fields] OR "trained"[All Fields] OR "training s"[All Fields] OR "trainings"[All Fields] OR "trains"[All Fields]))) AND ("physical therapy modalities"[MeSH Terms] OR ("physical"[All Fields] AND "therapy"[All Fields] AND "modalities"[All Fields]) OR "physical therapy modalities"[All Fields] OR "physiotherapies"[All Fields] OR "physiotherapy"[All Fields])) AND ((randomizedcontrolledtrial[Filter]) AND (2010:2023[pdat]))
Scopus, Research Gate	((("cerebral palsy"[MeSH Terms] OR ("cerebral"[All Fields] AND "palsy"[All Fields]) OR "cerebral palsy"[All Fields]) AND (("gait"[MeSH Terms] OR "gait"[All Fields]) AND ("education"[MeSH Subheading] OR "education"[All Fields] OR "training"[All Fields] OR "education"[MeSH Terms] OR "train"[All Fields] OR "train s"[All Fields] OR "trained"[All Fields] OR "training s"[All Fields] OR "trainings"[All Fields] OR "trains"[All Fields]))) AND ("physical therapy modalities"[MeSH Terms] OR ("physical"[All Fields] AND "therapy"[All Fields] AND "modalities"[All Fields]) OR "physical therapy modalities"[All Fields] OR "physiotherapies"[All Fields] OR "physiotherapy"[All Fields])) AND ((randomizedcontrolledtrial[Filter]) AND (2010:2023[pdat]))

Data collection process and data items

The process of data selection from the studies was carried out by both primary reviewers separately. They relied solely on the data provided by each article and did not seek additional information from the authors. In this way, the extracted data from each study includes: a) characteristics of the participants (age, gender, severity, and duration of the condition), b) the precise type of intervention (aerobic exercise, treadmill walking training, walking on the ground, etc.) and its parameters (duration of the intervention, duration of each session, number of sessions), and c) the type of outcome measure (mobility assessment using a rating scale), as well as the number and timing of each different measurement.

Quality assessment of the trials

The quality of the final studies included in the systematic review was assessed by the PEDro scale (Physiotherapy Evidence Database scale) (Maher et al., 2003). The PEDro scale consists of 11 items, which assess both the external and internal validity of the study. Only the first criterion relates to external validity and is not included in the final score. The validity of each study can be classified as poor (PEDro score 0–4), fair (PEDro score 5–6) or high (PEDro score 7–10). Each study was assessed by two reviewers. Any disagreements were resolved by discussion between them.

3 Results and Discussions

3.1 Results

Study selection

From the search conducted on the three databases, the initial entries were 673. The evaluation was based first on the titles, then on the abstracts of the studies and finally on reading the full text of the articles. So, after removing duplicate studies, there were 423 remaining, and following the exclusion of articles based on their titles, 20 studies were left for abstract reading. After reviewing the abstracts, 6 studies were excluded. Out of the 14 studies, 7 were further rejected after reading the full texts and in 1 there was no free access to the article, having exhausted all efforts to access the article by applying to the author. Therefore, a total of 6 articles met the criteria to be included in the qualitative synthesis of the systematic review. The process of study selection for this specific review is also presented graphically in Fig. 1.

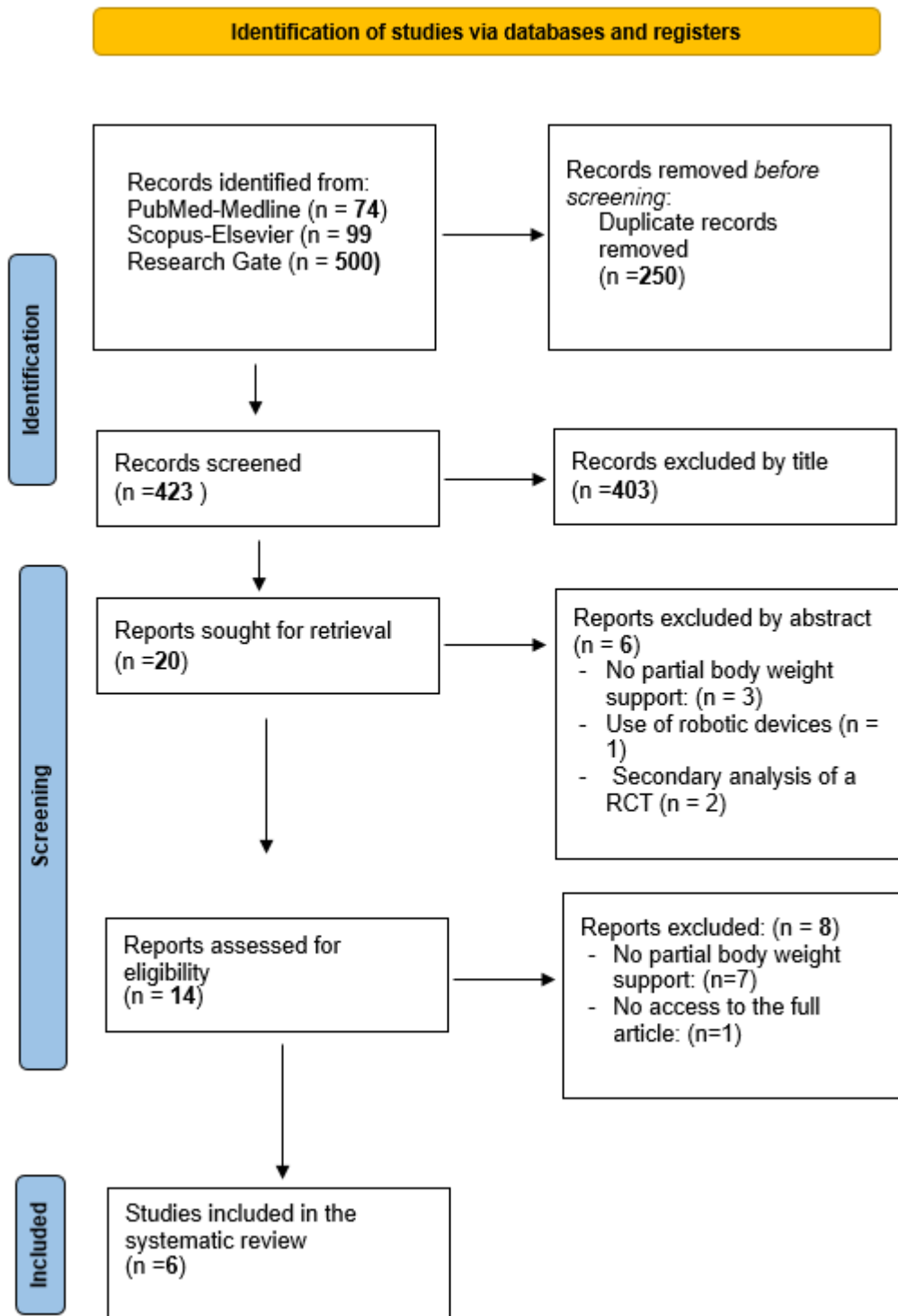


Figure 1. Flowchart of the process of searching and selecting the final studies for the systematic review (RCT: Randomised Controlled Trial)

Study characteristics

Of the 673 studies initially identified, only 6 studies met the entry criteria. Among the included studies, 1 was conducted in China (Su et al., 2013), 1 in Singapore (Swe et al., 2015), 1 in Australia (Willoughby et al., 2010), 1 in India (Kassim et al., 2022), 1 in Indonesia (Gunawan et al., 2022), and 1 in the United State (Johnston et al., 2011). The total sample size of participants who took part in these studies and completed the respective rehabilitation programs amounted to 160 individuals. In 5 out of the 6 studies (Willoughby et al., 2010; Su et al., 2013; Swe et al., 2015; Kassim et al., 2022; Gunawan et al., 2022) the average age ranged from 6 to 18 years, while in 1 study (Johnston et al., 2011) the average age was 2 to 7 years. The duration of the interventions varied from 8 to 24 weeks, and the functional assessment tools used in the measurement and evaluation of functionality included the Gross Motor Function Measure-66 and 88 (GMFM) in 5 studies (Johnston et al., 2011; Su et al., 2013; Swe et al., 2015; Kassim et al., 2022; Gunawan et al., 2022), the 10-meter walk test in 3 studies (Willoughby, 2010; Swe et al., 2015; Kassim et al. 2022), the 6-minute walk test in 1 study (Swe et al., 2015), the 10-minute walk test in 1 study (Willoughby et al., 2010), the School Function Assessment (SFA) in 1 study (Willoughby et al., 2010) and the Paediatric Outcomes Data Collection Instrument (PODCI) in 1 study (Johnston et al., 2011). The detailed characteristics of the sample, design, intervention and assessment for each study are shown in Table 2.

Table 2
Description of the studies used in the systematic review

Study (Year)	Sample	Intervention	Assessment	Results
Willoughby et al. (2010)	Participants n: 26 Group E/C: 12/14 Sex M/F: 15/11 Age: 5-18y GMFCS: III, IV	E: Treadmill training incorporating partial body weight support. C: Walking. E: Twice/week for 9 weeks. C: Twice/week for 9 weeks.	Baseline, 10, and 24 weeks	Children with CP can no longer improve their walking speed and endurance with 9 weeks of PBWSTT. PBWSTT was found to be no more effective than ground walking in terms of improving walking speed and endurance
Johnston et al. (2011)	Participants n: 26 Group E/C: 14/12 Sex M/F: 14/12 Age: 6-13y GMFCS: -	E: Treadmill with partial body weight support. C: Strengthening exercise. E: Twice daily/5 days a week for 10 weeks. C: Twice daily/5 days a week for 10 weeks.	Baseline and 12 weeks	There is no difference in gain in spatiotemporal parameters (such as gait speed and cadence) between PBWSTT and exercise interventions. Only the treadmill group retained profits after the withdrawal of the intervention
Su et al. (2013)	Participants n: 8 Group E/C: 4/4 Sex M/F: 6/2 Age: 6-17y GMFCS: II - V	E: Treadmill with partial body Weight support followed by conventional gait training. C: Conventional gait training followed by a treadmill with partial body weight support. E: 3 times a week 30min for 24 weeks	Baseline and 24 weeks	PBWSTT: improvement in walking speed, higher GMFM scores There were no differences between the 2 training methods.

Study (Year)	Sample	Intervention	Assessment	Results
Swe et al. (2015)	Participants n: 30 Group E/C: 15/15 Sex M/F: 20/10 Age: 12-18y GMFCS: II, III	C: 3 times a week 30 min for 24 weeks E: Treadmill training incorporating partial body weight support. C: Above the ground. E: 2 times 30 min/week for 8 weeks C: 2 times 30 min/week for 8 weeks	Baseline, 4 weeks, and 8 weeks	After eight weeks of PBWSTT, children with mild to moderate CP had improved gross motor functions and walking speed. PBWSTT is no more effective than ground walking training.
Kassim et al. (2022)	Participants n: 60 Group E/C: 40/20 Sex M/F: 66,7% - 33,3% Age: 6,3y GMFCS: III, IV	E: Body weight support overground training. E: Body weight support treadmill training. C: Conventional gait training. E: 8-week training C: 8-week training	Baseline and 8 weeks	Gross motor function, cadence, stride, and walking all significantly improved with the PBWSTT. BWSOGT had better outcomes than PBWSTT and the control group.
Gunawan et al. (2022)	Participants n: 10 Group E/C: 5/5 Sex M/F: 4/6 Age: 48,4 - 63,4 month GMFCS: I, II, III	E: usual physiotherapy and treadmill with partial body weight support. C: usual physiotherapy E: usual ph/th 2 times/week of 20 min and PBWSTT 2 times/week of 20 min. 20 sessions C: 2 times/week of 20 min, 20 sessions	Baseline and 20 practice sessions	The treatment group had a higher GMFM - E score than the control group

RCT: Randomized Controlled Trial, PBWSTT: Partial Body Weight Support Treadmill Training, BWSOGT: Body Weight Support Over ground Training, GMFM: Gross Motor Function Measure, GMFCS: Gross Motor Function Classification System, SSTTEP: Supported Speed Treadmill Training Exercise Program)

Quality of studies

Regarding the quality of the 6 studies ultimately included in the systematic review, their assessment using the PEDro scale (Physiotherapy Evidence Database scale) revealed that 1 study (Swe et al., 2015; Moseley et al., 2002) has a high level of methodological quality, 4 (Willoughby et al., 2010; Johnston et al., 2011; Kassim et al., 2022; Gunawan et al., 2022) have a moderate level and the 1 (Su et al., 2013) remaining have a poor level. The average score across the studies included, based on the PEDro scale, is 5.3, indicating a moderate methodological quality of the systematic review studies.

Effectiveness of the interventions

All the studies processed and analyzed in this specific systematic review demonstrated that treadmill walking with partial body weight support (PBWSTT) can positively contribute to improving the walking ability of individuals with Cerebral Palsy.

More specifically, for PBWSTT, the results of all 6 studies showed an increase in scores on the Gross Motor Function Measure (GMFM) scale and an improvement in walking patterns, speed, endurance, and rhythm. Concerning the comparison of PBWSTT with over-ground walking, the results of 3 studies did not show statistically significant differences between the two methods, leading to the conclusion that PBWSTT is not more effective than conventional over-ground walking training (Su et al., 2013; Swe et al., 2015; Willoughby et al., 2010).

On the other hand, the study by Kassim et al. (2022), comparing PBWSTT with overground walking with partial body weight support (BWSOGT) and conventional walking exercise (control group), concluded that BWSOGT had better outcomes than PBWSTT and the control group. Additionally, both PBWSTT and BWSOGT appeared to be more effective than conventional walking training without body weight support. The research by Gunawan et al. (2022), supported the same conclusion, demonstrating that PBWSTT is more effective than conventional ground-based physical therapy. Finally, the study by Johnston et al. (2011), showed that although both groups (SSTTEP group and control group) had improvement in walking and functionality, only the SSTTEP group managed to maintain this improvement over time.

Association of PEDro scoring and intervention effectiveness

Observing the forms of intervention and their effectiveness with their scores for methodological quality according to the PEDro scale, it seems that the study by Swe et al. (2015), which concludes that PBWSTT is no more effective than conventional physical therapy and ground walking, has a high level (> 7/10), and to be more specific, it was scored 8/10. Additionally, the studies by Willoughby et al. (2010) and Johnston et al. (2011), scored 6/10 and 4/10 and aligned with the previous study. Also, the studies by Kassim et al. (2022) and Gunawan et al. (2022), demonstrated that treadmill walking with partial body weight support has better results compared to ground walking with partial body weight support (BWSOGT) and that the combination of regular physical therapy and PBWSTT is a more effective intervention than applying only regular physical therapy, scored at 6/10 and 5/10, respectively. Finally, the study by Su et al. (2013), showed no statistically significant difference between the two training methods they followed and it also scored very low at 3/10.

Table 3

Assessment of the methodological quality of the studies for adherence to quality criteria and risk of bias based on the Pedro scale. Each number in the first row of the table refers to the corresponding criterion of the scale. (*: the first criterion is not included in the final score, -: the criterion was not met, ✓: the criterion was met).

Study	1*	2	3	4	5	6	7	8	9	10	11	Score	Quality level
Willoughby et al (2010)	✓	✓	✓	-	-	-	✓	-	✓	✓	✓	6/10	Fair
Johnston TE et al (2011)	✓	✓	-	✓	-	-	-	-	-	✓	✓	4/10	Fair
Su et al (2013)	✓	✓	-	-	-	-	-	-	-	✓	✓	3/10	Poor
Swe N et al (2015)	✓	✓	✓	✓	-	-	✓	✓	✓	✓	✓	8/10	High
Kassim et al (2022)	✓	✓	-	✓	-	-	✓	✓	-	✓	✓	6/10	Fair
Gunawan et al (2022)	✓	-	-	✓	-	-	✓	-	✓	✓	✓	5/10	fair

Number matching criteria. 1: The report describes the source of subjects and a list of criteria used to determine who was eligible to participate in the study, 2: Subjects were randomly allocated to groups, 3: Concealed allocation, 4: The groups were similar at baseline regarding the most important prognostic indicators, 5: Blinding of all subjects, 6: Blinding of therapists, 7: Blinding of assessors, 8: Measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups, 9: "Intention

to treat” analysis, 10: The results of between-group statistical comparisons are reported for at least one key outcome, 11: the study provides both point measures and measures of variability for at least one key outcome

3.2 Discussion

The present systematic review found that treadmill training with partial body weight support PBWSTT leads to an increase in scores on the GMFM scale, as well as improvement in walking patterns, speed, endurance, and rhythm. However, when comparing PBWSTT with conventional training and ground walking, it is challenging to precisely determine which method is superior, as the included studies in this review yielded different results.

Specifically, studies by [Willoughby et al., \(2010\)](#); [Johnston et al., \(2011\)](#); and [Swe et al., \(2015\)](#); concluded that PBWSTT is not more effective than conventional physical therapy and ground walking, as the differences between groups were not statistically significant. On the other hand, the study by [Kassim et al. \(2022\)](#), showed that ground walking with partial body weight support (BWSOGT) has better results compared to treadmill walking with partial body weight support. Furthermore, both PBWSTT and BWSOGT appeared to be more effective than conventional walking training without body weight support. Similar findings were reported in the study by [Gunawan et al. \(2022\)](#), which demonstrated that the combination of regular physical therapy and PBWSTT is a more effective intervention for children with Cerebral Palsy compared to applying only regular physical therapy.

Also, it is important to note that a series of techniques in conventional gait training is not applicable, especially when targeting adolescents with higher body weight or children with low functionality and non-spastic CP ([Su et al., 2013](#)). So, PBWSTT may offer a new opportunity for gait training in these patient groups. Moreover, concerning the clinical significance of the results, in this systematic review, PBWSTT seems to have positive effects on improving walking and motor functions in individuals with Cerebral Palsy. These could serve as motivation for physical therapists to incorporate this method into their intervention programs, provided they have the necessary expertise and equipment.

It is essential to note the limitations of this systematic review. The small number of participants in the included studies limits the generalization of results to a broader population and prevents drawing secure conclusions. Additionally, the lack of long-term follow-up in most studies hinders understanding the duration of the intervention effects. The heterogeneous nature of the types and stages of Cerebral Palsy in the included studies also makes it challenging to generalize the results for specific patient groups.

Future research is recommended to focus on conducting randomized controlled trials with higher methodological quality for more robust outcomes. Including more therapists, each assessing, treating, and evaluating participants independently, could enhance objectivity and minimize potential errors.

4 Conclusion

The effect of treadmill training with partial body weight support (PBWSTT) has a positive impact on improving the walking ability of patients with Cerebral Palsy. However, when it comes to comparison, the question of whether PBWSTT is more effective than conventional physiotherapy and floor walking exercise cannot be conclusively answered yet, highlighting the importance of conducting further research in this field. Finally, future research needs to focus on obtaining more randomised control trials with a larger number of participants as well as investigating this intervention in specific types of cerebral palsy and age groups of patients.

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Biography of Authors

	<p>Xanthi Chrysoula Enrolled in the Department of Physiotherapy at the University of Thessaly in Greece in September 2019 and graduated in March 2024. During her academic journey, she actively attended various educational conferences and participated in the university's journal club. Additionally, she successfully completed her undergraduate thesis focusing on neurological physiotherapy. <i>Email: cxanthi@uth.gr</i></p>
	<p>Stamelaki Magdalini enrolled in the Department of Physiotherapy at the University of Thessaly in Greece in September 2019 and graduated in March 2024. During her academic journey, she actively participated in various educational conferences, served as a founding member of the university's journal club, and was also a founding member of the first physiotherapy student conference in Greece. Additionally, she successfully completed her undergraduate thesis focusing on neurological physiotherapy. <i>Email: mstamelaki@uth.gr</i></p>
	<p>Dimitriadis Zacharias He is Associate Professor at the Physiotherapy Department of the University of Thessaly. He has obtained a BSc Physiotherapy from TEI Athens (currently known as University of West Attica, 2005), an MSc Physiotherapy (Neuro-adult route) from Cardiff University (2008) and a PhD Musculoskeletal from the School of Translational Medicine of the University of Manchester (2011). His research interests are concerned with the spinal pain and postural disorders, manual therapy, motor control and development and validation of assessment tools for musculoskeletal and neurological patients. He is currently teaching under- and postgraduate modules related to manual therapy, soft tissue mobilization, ergonomics, clinical musculoskeletal physiotherapy and research methods. He has participated in a number of clinical seminars relative to the rehabilitation of patients with neuromusculoskeletal and neurological problems and he has rich clinical experience in different rehabilitation settings. He has more than 40 publications in national and international peer-reviewed journals and more than 300 citations (h index: 9). He is reviewer in many different international peer-reviewed journals. He has participated in many national and international conferences either by presenting his work or as a member of scientific committees.</p>
	<p>Paras Georgios He is a Assistant Professor at the University of Thessaly (Department of Physiotherapy). He has Bachelor Degree in Physiotherapy (1996) from the National Sports Academy "Vasil Levski" (Faculty of Physiotherapy) in Sofia. He received his Ph.D. Degree (2002) from the same University - Faculty: Physiotherapy & Rehabilitation. His field of expertise is Neurological Physiotherapy. His research interests span the areas of pediatric neurological rehabilitation. He is a member of Human Performance and Rehabilitation Laboratory. He is tutor in undergraduate and postgraduate programs in physiotherapy. He is also a member of the Scientific Council of the Panhellenic Physiotherapy Association. He has attended numerous postgraduate courses and specialized clinical seminars. He has publications, participations in scientific conferences and has been a member of research groups in research projects.</p>
	<p>Besios Thomas He is an Assistant Professor at the University of Thessaly (Department of Physiotherapy), Lamia. Postgraduate degree of the Democritus University of Thrace in the Department of Science and Physical Education specializing in Prevention - Intervention - Rehabilitation (2006). Postgraduate degree of the Department of Physiotherapy of Thessaloniki specializing in Pediatric Physiotherapy (2016). Ph.D. from the Democritus University of Thrace in Neurological rehabilitation (2018). He is the Deputy Director of the Research Laboratory of Human Performance and Rehabilitation and has been a member of research teams in research projects. He has published in scientific journals, member of scientific and organizational committees of conferences and has participated in several postgraduate courses and specialized clinical seminars. His field of expertise is Neurological Physiotherapy in children and adults. His research interests span the areas of neurological rehabilitation, assessment tests and treatment of neurological disorders. <i>Email: tbesios@uth.gr</i></p>

Xanthi, C., Stamelaki, M., Dimitriadis, Z., Paras, G., & Besios, T. (2024). The effectiveness of partial body weight support treadmill training on walking in people with cerebral palsy : A systematic review. International Journal of Health Sciences, 8(2), 108–119. <https://doi.org/10.53730/ijhs.v8n2.14912>