Addition of backward walking training to forward walking training improves walking speed in children with cerebral palsy: a systematic review with meta-analysis

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The objective was to examine the effects of backward walking training for improving walking speed and balance in children with cerebral palsy. A systematic review of randomized trials was conducted. Trials had to include children with cerebral palsy, with a Gross Motor Function Classification System, between I and III, that delivered backward walking training as a solo intervention or in combination with forward walking training. The outcomes of interest were walking speed and balance. The methodological quality of included trials was assessed by the PEDro scale, and the quality of evidence was assessed according to Grading of Recommendations Assessment, Development and Evaluation. Eight papers, involving 156 participants, were included. Using random-effects meta-analysis, we estimated that backward walking training improved walking speed by 0.10 m/s [95% confidence interval (CI) 0.05–0.16] and by 2 points on the Pediatric Balance Scale (0–56) (95% CI 1.5–2.2) more than forward walking training. We also estimated that the addition of backward walking training increased walking speed by 0.20 m/s (95% CI 0.07–0.34) and reduced the angular excursion of the center of gravity by 0.5 degrees (95% CI −0.7 to −0.3). The quality of the evidence was classified as low to moderate. In conclusion, overall, backward walking training appears to be as effective or slightly superior to forward walking training for improving walking speed in children with CP. The addition of backward walking training statistically significantly and clinically important enhanced benefits on walking speed. *International Journal of Rehabilitation Research* 46: 300–307 Copyright © 2023 Wolters Kluwer Health, Inc. All rights reserved.

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Introduction

Cerebral palsy (CP) is a non-progressive permanent disorder of movement and posture attributed to disturbances in the developing fetal and infant brain [1]. CP is the most common cause of physical disability in childhood, and its prevalence ranges from 1.5 to 3 per 1000 live births [2]. Although the initial neuropathologic lesion is non-progressive, children with CP may develop a range of secondary conditions over time that includes limited coordination and motor control, joint contractures, disturbances of sensation, perception, cognition, and self-reported factors such as pain and fatigue [3–5]. Those impairments are typically related to decreased cardiorespiratory fitness and activity limitations on upper limb activities and walking, which restrict participation [3–5].

Being able to walk partially contributes to independence in daily activities [6] and has been described as an important rehabilitation goal by parents of children with CP and health care professionals [7,8]. Previous studies indicated that practice of forward walking provides an increased opportunity to train the entire walking cycle, which facilitates an enhanced gait pattern in children with CP [9]. More recently, backward walking has been recommended to help improving the components of forward walking, due to the recruitment of specialized control circuits [10]. First, the backward walking emphasizes the positioning of the foot behind the body, which facilitates hip extension while performing knee flexion. This can be useful for children who have synergistic influences in the lower extremity [10]. Second, concentric muscle activity in forward walking would become eccentric activity in backward walking and vice versa, leading to a more efficient recruitment of motor units and improvement of walking abilities [11]. Moreover, backward walking adds challenge to balance and walking training as it is more difficult and demanding than forward walking due to its postural instability [12].

One previous systematic review, based on 7 randomized trials, suggested benefits of backward walking training on balance, gross motor function, and walking in children with CP [13]. However, the magnitude and uncertainty of effects sizes were not estimated due to the absence of a meta-analysis. The protocol of the present systematic

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review has been designed to improve previous methods by separately comparing (1) backward walking training with forward walking training and (2) backward walking training in addition to forward training with forward walking training. Second, the Grading of Recommendations Assessment, Development and Evaluation (GRADE) system was incorporated to quantify the quality of the evidence [14]. Lastly, this review planned meta-analyses to estimate the magnitude and precision of the effects of intervention.

The specific research questions were:

(1) In children with CP, are the effects of backward walking comparable with forward walking for improving walking speed and balance?
(2) Does the addition of backward walking to forward walking help improve the benefits of forward walking?

Methods

Design

The review is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement guidelines, and previously registered (PROSPERO CRD42022357558).

Identification and selection of trials

Searches were conducted on AMED (1985 to August 2022), EBM Reviews - Cochrane Central Register of Controlled Trials (August 2022), EBM Reviews - Cochrane Database of Systematic Reviews (2005 to August 2022), LILACS (1986 to August 2022), MEDLINE (1946 to August 2022), PEDro (to August 2022), and Scielo (August 2022) databases for relevant studies, without date or language restrictions. The search strategy was registered at PubMed/Medline and the authors received notifications regarding potential papers related to this systematic review. Search terms included words related to CP, and words related to *backward walking*. Titles and abstracts were displayed and screened (K.K.P.M.), to identify relevant studies. Full-text copies of peer-reviewed relevant papers were retrieved, and their reference lists were screened, to identify further relevant studies. The method section of the retrieved papers was extracted and independently reviewed by two researchers (P.R.A. and L.R.N.), using the following criteria: randomized trials, including children with CP, which delivered backward walking training, and investigating the effects on o walking speed and balance. Both reviewers were blinded to authors, journals, and results of the studies. Disagreements or ambiguities were solved by consensus, after discussion with a third reviewer (K.K.P.M.).

Assessment of characteristics of trials

Methodological Quality

The methodological quality of included trials was assessed by extracting PEDro Scale scores from the Physiotherapy Evidence Database (www.pedro.org.au). The PEDro Scale has 11 items, designed for rating the methodological quality (internal validity and statistical information) of randomized trials. Each item, except for Item 1, contributes one point to the total PEDro score (range 0–10 points). Where a trial was not included on the database, it was independently scored by two reviewers, who had completed the PEDro scale training tutorial.

Participants

To be eligible for inclusion, trials had to include children with CP, with a Gross Motor Function Classification System (GMFCS), between I-II (independently ambulatory) or III (ambulatory with assistive devices), or the trials should clearly report that all children were able to walk. Number of participants, age, and GMFCS were recorded to assess similarity among the studies.

Intervention

The intervention of interest was backward walking training, delivered either as a solo intervention or in combination with forward walking training. Walking training had to be comprised of planned, structured, and repetitive exercises delivered with the purpose of improving walking [15]. The control intervention could be forward walking training. Session duration, session frequency and program duration were recorded to assess the similarity of the studies.

Outcome measures

The outcomes of interest were walking speed and balance. Walking speed is typically obtained using a timed walk test (e.g. 10-m walk test) or movement analysis systems. The measurement of balance had to be representative of the ability to maintain a controlled body position during an activity, assessed by three-dimensional movement analysis system or questionnaires.

Data analysis

Two reviewers independently extracted information regarding the method (i.e. design, participants, intervention, outcome measures) and results [i.e. number of participants, and mean (SD) of outcomes of interest], which were checked by a third reviewer. When information was not available in the published trials, details were requested from the corresponding author. For meta-analysis, where possible, change scores rather than post-intervention scores were used to obtain the pooled estimate of the effect of the intervention, using a random-effect model. The analyses were performed using the Comprehensive Meta-Analysis Program, version 3.0. A visual inspection of the distribution of effect sizes in the forest plots was performed and the I^2 value was calculated to indicate the proportion of variance that was due to heterogeneity [16,17]. Values of I^2 greater than 50% are indicative of important heterogeneity [16,18].

The critical value for rejecting the null hypothesis was set at a level of 0.05 (two-tailed). The pooled data for each outcome were reported as differences between experimental and control groups and their 95% confidence intervals (95% CI). When data were not available to be included in the pooled analyses, between-group results were reported.

The GRADE system was used to summarize the overall quality of evidence for each outcome. The GRADE system ranges from high to very low quality [14]. We rated evidence from the high-quality level and downgraded it one point if one of the following prespecified criteria was present: low methodological quality (most of trials with PEDro score < 6); inconsistency of estimates among pooled studies ($I^2 > 50\%$), or when assessment was not possible (no pooling); indirectness of participants (over 50% of the studies did not report participants' GMFCS); and imprecision (pooling < 300 participants for each outcome) [19,20]. Two reviewers (K.K.P.M. and P.R.A.) assessed the quality of the evidence using the GRADE system, with potential disagreements resolved by consensus.

Results

Flow of trials through the review

The electronic search strategy identified 909 papers. After screening titles, abstracts, and duplicated papers, 21 potentially relevant full papers were retrieved, but 13 failed to meet the inclusion criteria. Thus, 8 papers were included in this systematic review (Fig. 1) [21–28].

Characteristics of the included trials

The eight studies involved 156 participants and investigated the effect of backward walking training on walking speed (n = 6), and balance (n = 3) (Table 1).

Methodological quality

The mean PEDro score of the included trials was 5.4 (range 3–7) (Table 2). All trials had randomly allocated participants, and reported between-group differences, as well as point estimate and variability. Most trials had similar groups at baseline (88%). Half of the studies had less than 15% dropouts and reported blinding of assessors. On the other hand, most trials did not report allocation concealment (75%), or whether an intention-to-treat analysis was undertaken (75%). No trials blinded participants or therapists, which is difficult or impossible in complex interventions.

Participants

The mean age of participants ranged from 6 to 12 years across trials. Five trials included participants with GMFCS levels of I and II, one trial with levels of II and III, one trial with levels from I to III. One trial did not report the GMFCS level of the participants.

Intervention

In all trials, the experimental intervention was backward walking training, which was delivered either overground [21,24–26] or on treadmills [22,23,27,28]. Training was progressed by reducing manual assistance or body weight support, by training away from parallel bars, or by increasing walking speed, distance, or the treadmill inclination. Overall, participants undertook training for 20–40 min, 3 times per week, for 3–12 weeks. Three trials [21,24,25] investigated the effect of backward walking in comparison with forward walking, and five trials investigated the addition of backward walking to forward walking [22,23,26–28].

Outcome measures

Six trials [21,23–25,27,28] measured walking speed using a three-dimensional movement analysis system, which was reported in m/s. Two trials [22,26] measured balance using a three-dimensional movement analysis system, and one trial [25] used a questionnaire (Pediatric Balance Scale).

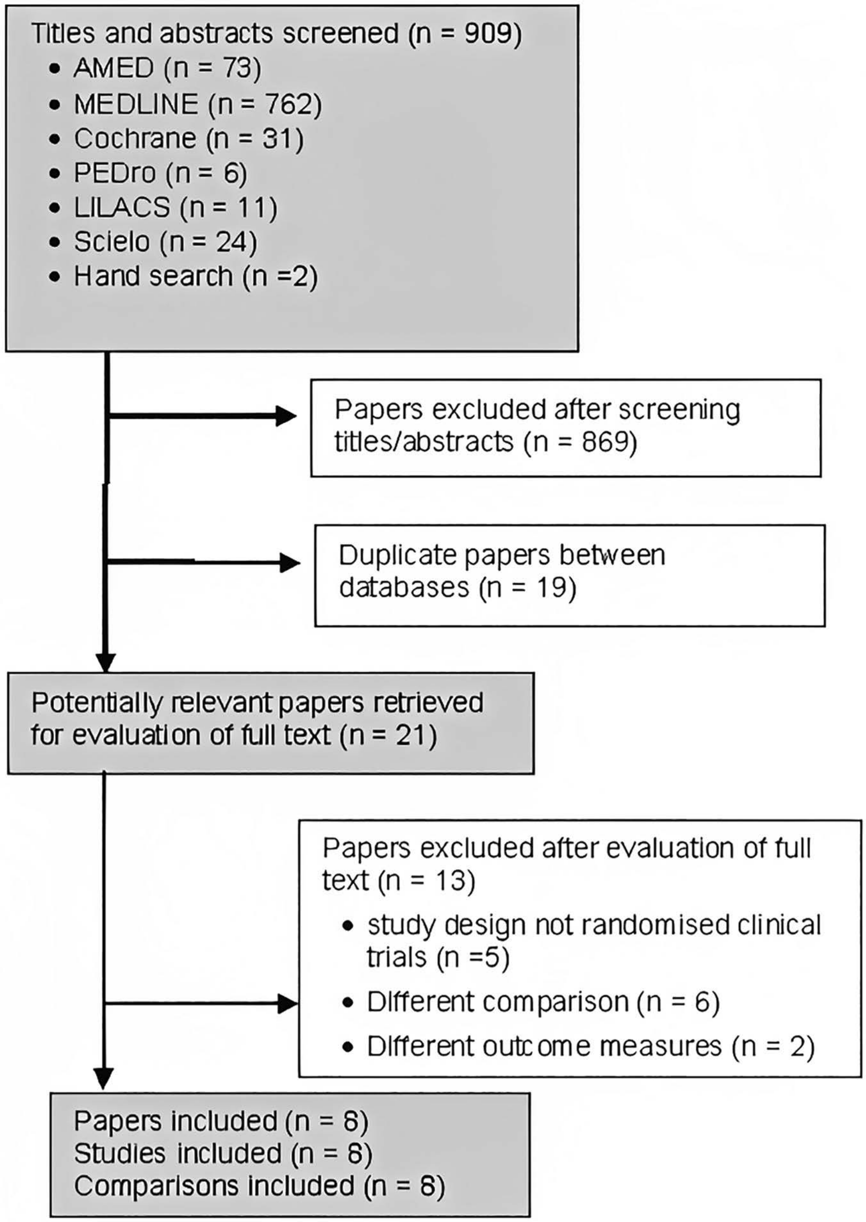
Backward walking training versus forward walking training

Three trials [21,24,25], involving 54 participants, compared backward walking training with forward walking training on walking speed. The pooled estimate indicated that backward walking training improved walking speed by 0.10 m/s (95% CI 0.05–0.16, $I^2 = 0\%$, $P = 0.001$) more than forward walking training (Fig. 2, see Figure 5 for the detailed forest plot, Supplemental digital content 1, http://links.lww.com/IJRR/A46). The quality of evidence was rated as moderate. Only one trial [25], which examined the effects on balance, indicated that backward walking training improved by 2 points on the Pediatric Balance Scale (0–56) (95% CI 1.5–2.2, $P < 0.001$) more than forward walking training. The quality of evidence was rated as low.

Addition of backward walking training to forward walking training

Three trials [23,27,28], involving 42 participants, investigated the effect of the addition of backward walking training to forward walking training on walking speed. The pooled estimate indicated that the addition of backward walking training increased walking speed by 0.20 m/s (95% CI 0.07–0.34, $I^2 = 7\%$, $P = 0.003$) (Fig. 3, see Figure 6 for the detailed forest plot, Supplemental digital content 1, http://links.lww.com/IJRR/A46). The quality of evidence was rated as low. Two trials [22,26], involving 60 participants, investigated the effect of the addition of backward walking training to forward walking training on balance, by measuring the angular excursion of a patient's center of gravity (degrees). The pooled estimate indicated that the addition of backward walking training reduced the angular excursion of the

Fig. 1



Flow of studies through the review.

center of gravity by 0.5 degrees (95% CI −0.7 to −0.3, $I^2 = 0\%$, $P < 0.001$) (Fig. 4, see Figure 7 for the detailed forest plot, Supplemental digital content 1, http://links.lww.com/IJRR/A46). The quality of evidence was rated as low.

Discussion

This is the first systematic review with meta-analysis to investigate the effect of backward walking in children with CP. We found moderate quality evidence that backward walking training is slightly superior to forward walking training for improving walking speed and balance in children with CP. Moreover, low-quality evidence indicated that the addition of approximately 20 min of backward walking training to forward walking training significantly improves walking speed and reduces the angular excursion of the center of gravity.

The review included 3 trials that directly compared backward and forward walking; because trials matched therapy intensity, the results can be attributed primarily to the mode of intervention. Although significant effects in favor of backward walking were found for walking speed and balance, the magnitude of the

Table 1 Characteristics of included studies (n = 8)

Study	Participants	Walking intervention		Walking outcomes measured[b]
		Frequency and duration[a]	Parameters	
Abdel-aziem and El-Basatiny (2017) [21]	n = 30 Age (yr) = 12 (1) GMFCS = I and II	Exp = backward walking 25 min × 3/wk × 12 wk Con = forward walking 25 min × 3/wk × 12 wk Both = regular physical therapy Not reported × 3/wk × 12 wk	Environment = overground and parallel bars. Assistance = manual, on subjects' leg. Progression = ↓ manual assistance + parallel bars, ↑ distance + speed.	Speed (m/s)
Abdou *et al*., (2014) [22]	n = 30 Age (yr) = 6 (1) GMFCS = Not reported	Exp = backward walking 20 min × 3/wk × 6 wk Con = no backward walking Both = regular physical therapy Not reported × 3/wk × 6 wk	Environment = treadmill Assistance = not reported. Progression = ↑ treadmill speed from 1.2 up to 1.6 m/s.	Balance (Biodex balance system)
Ayoub (2016) [23]	n = 20 Age (yr) = 8 (1) GMFCS = II and III	Exp = backward walking 15 min × 3/wk × 12wk Con = no backward walking Both = regular physical therapy Not reported × 3/wk × 12 wk	Environment = Treadmill Assistance = body weight support. Progression = ↑ treadmill speed from 0.01 up to 2.0 m/s.	Speed (m/s)
Choi *et al*., (2019) [24]	n = 12 Age (yr) = 10 (3) GMFCS = I and II	Exp = backward walking 40 min × 3/wk × 3 wk Con = Forward walking 40 min × 3/wk × 3 wk	Environment = overground Assistance = manual, on subjects' leg. Progression = ↓ manual assistance + ↑ distance + speed.	Speed (m/s)
Choi *et al*., (2021) [25]	n = 12 Age (yr) = 10 (3) GMFCS = I and II	Exp = backward walking 40 min × 3/wk × 4 wk Con = forward walking 40 min × 3/wk × 4 wk	Environment = overground Assistance = manual, on subjects' leg. Progression = ↓ manual assistance + ↑ distance + speed.	Speed (m/s) Balance (Pediatric Balance Scale)
El-Basatiny and Abdel-aziem (2015) [26]	n = 30 Age (yr) = 12 (1) GMFCS = I and II	Exp = backward walking 25 min × 3/wk × 12 wk Con = no backward walking Both = regular physical therapy 60 min 3/wk × 12 wk	Environment = Overground and parallel bars. Assistance = manual, on subjects' leg. Progression = ↓ manual assistance + parallel bars, ↑ distance + speed.	Balance (Biodex balance system)
Hösl *et al*., (2018) [27]	n = 10 Age (yr) = 12 (4) GMFCS = I and II	Exp = backward walking 25 min × 3/wk × 9 wk Con = no backward walking	Environment = Treadmill Assistance = body weight support. Progression = ↑ treadmill speed + ↑ in slope	Speed (m/s)
Sanad (2017) [28]	n = 12 Age *(yr)* = from 5 to 9 GMFCS = I, II and III	Exp = backward walking 20 min × 3/wk × 12 wk Con = no backward walking Both = regular physical therapy 60 min 3/wk × 12 wk	Environment = treadmill Assistance = not reported. Progression = ↑ treadmill speed from 0.01 up to 2.0 m/s.	Speed (m/s)

[a]Con, control group; Exp, experimental group; GMFCS, Gross Motor Function Classification System.
[b]Outcome measures listed are only those that were analyzed in this systematic review.

Table 2 PEDro criteria and scores for the included studies (n = 8)

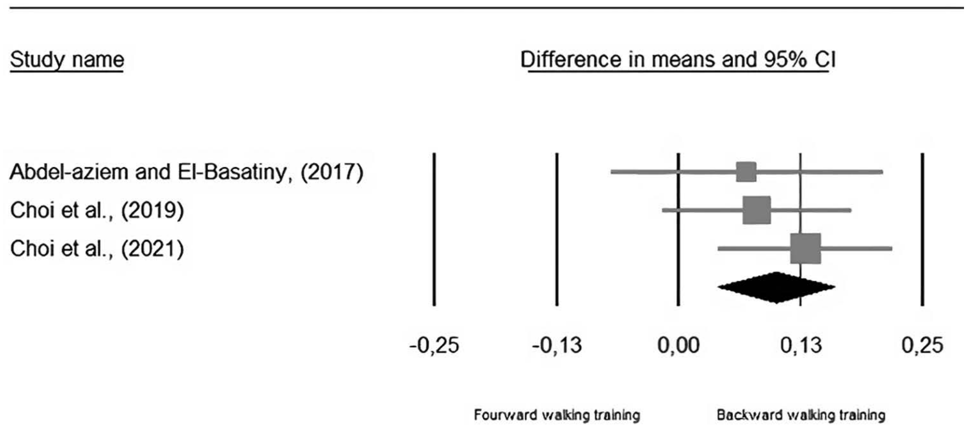
Study	Random allocation	Concealed allocation	Groups similar at baseline	Participant blinding	Therapist blinding	Assessor blinding	<15% dropouts	Intention-to-treat analysis	Between-group difference reported	Point estimate and variability reported	Total (0–10)
Abdel-aziem and El-Basatiny (2017) [21]	Y	Y	Y	N	N	Y	Y	N	Y	Y	7
Abdou *et al*., (2014) [22]	Y	N	Y	N	N	N	N	N	Y	Y	4
Ayoub (2016) [23]	Y	N	Y	N	N	N	N	N	Y	Y	4
Choi *et al*., (2019) [24]	Y	N	Y	N	N	Y	Y	Y	Y	Y	7
Choi *et al*., (2021) [25]	Y	N	Y	N	N	Y	Y	Y	Y	Y	7
El-Basatiny and Abdel-aziem (2015) [26]	Y	Y	Y	N	N	Y	Y	N	Y	Y	7
Hösl *et al*., (2018) [27]	Y	N	Y	N	N	N	N	N	Y	Y	4
Sanad (2017) [28]	Y	N	N	N	N	N	N	N	Y	Y	3

N = no, Y = yes.

difference was not clinically relevant. This indicates that both modes of intervention can be delivered depending upon patients' preference and availability of resources. The benefits that emerge from backward walking are probably related to the biomechanical characteristics of the intervention, which incorporates active hip and knee extension with ankle dorsiflexion in combination with motor coordination training, and more postural demand [12,29].

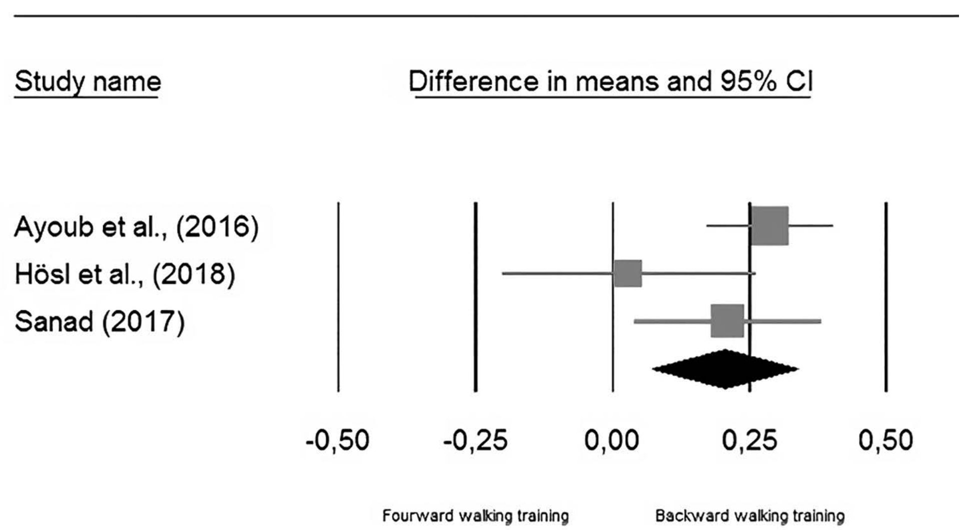
This review is also set up to answer if the addition of backward walking to forward walking would enhance walking benefits. The results on walking speed doubled with the addition of approximately 20 min of backward walking. The improvement of 0.2 m/s in walking speed, which

Fig. 2



Mean difference (95% CI) of effect of backward walking training versus forward walking training on walking speed, m/s (n = 54). CI, confidence interval.

Fig. 3

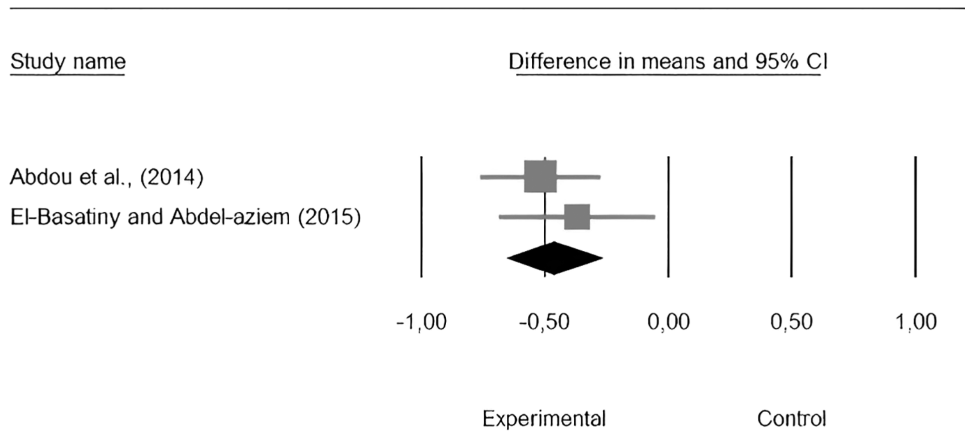


Mean difference (95% CI) of effect of the addition of backward walking training to forward walking training on walking speed, m/s (n = 42). CI, confidence interval.

represents a 35% improvement according to the participants' baseline measurement (0.58 m/s), is sufficient to be considered clinically relevant. This reinforces the finding that both modes of training can be delivered to children with CP; moreover, it suggests that the amount of training can be increased when different tasks are implemented, reducing monotony in training sessions leading to activity improvements. Previous studies have indicated that the duration of interventions is associated with improvements in outcomes among the children with CP [30]. This is in accordance with recent recommendations that providing extra therapy to people with neurological conditions improves clinically relevant outcomes [31].

The GRADE system of qualifying evidence suggested that only one of the four analyses (two outcomes and two comparisons) examined in this review was credible (i.e. provided moderate quality evidence). The main reason that no outcome provided high-quality evidence was the low number of participants in the meta-analyses. There were several factors that contributed to this. First, there was an average of 20 participants (range 10–30) for the trials included in the meta-analyses. In addition, although eight studies were included in the review, the analyzes included a maximum of three studies for each comparison. Therefore, large trials are still required to explore the benefits of backward walking training in CP. Moreover,

Fig. 4



Mean difference (95% CI) of effect of the addition of backward walking training to forward walking training on balance, degrees (n = 60). CI, confidence interval.

appropriate data reporting that includes both point measures and measures of variability at all timepoints or provision of data from individual participants is encouraged to enable data usage in further conventional or individual-patient-data meta-analyses [32].

This review has both strengthens and limitations. A major strength of this review was that research questions were separated into effects of backward walking in comparison with forward walking and effects of the addition of backward walking to forward walking; this allowed a meta-analysis and provided important insights to guide clinical practice. That is, both modes of intervention are effective, but the combination of modes allowed more amount of practice and resulted in 0.2 m/s additional improvement in walking speed, which is clinically relevant. On the other hand, it was disappointing that most recent trials were not of high methodological quality and did not include larger samples. That is, limitations identified in a previous systematic review [13] were not rectified by recent trials.

In conclusion, backward walking training appears to be as effective or slightly superior to forward walking training for improving walking speed in children with CP. The addition of 20 min of backward walking training, three times per week, for 12 weeks significantly enhanced benefits on walking speed, but the effects on balance are still uncertain. As the quality of the evidence was classified as low to moderate, large well-designed trials are still required to improve precision of estimates.

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Conflicts of interest

There are no conflicts of interest.

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