Effects of backward gait training on balance, gross motor function, and gait in children with cerebral palsy: a systematic review

Ahmed M Elnahhas, Shorouk Elshennawy and Maya G Aly

Abstract
Objective: To investigate the effects of backward gait training on balance, gross motor function, and gait parameters in children with cerebral palsy.
Data sources: PubMed, Cochrane Library, Web of Science, Science Direct, Physiotherapy Evidence Database (PEDro), and Google Scholar were searched up to May 2018.
Review methods: Randomized controlled trials were included if they involved any form of backward gait training for children with cerebral palsy. Two authors independently screened articles, extracted data and assessed the methodological quality using PEDro scale, with any confliction resolved by the third author. Modified Sackett Scale was used to determine the level of evidence for each outcome.
Results: Out of 1492 papers screened, 7 studies with 172 participants met the inclusion criteria. The duration of treatment ranged from 15 to 25 minutes, three times a week and for 6–12 weeks. The quality of studies ranged from good (two studies) to fair (four studies) and poor (one study), with a mean PEDro score of 4.7 out of 10. All included studies showed positive effects in the measured outcomes. The results showed level 1b evidence for balance when compared to no intervention, and for gross motor function, step length and walking speed when compared to same dose of forward gait training. The clinical heterogeneity of studies makes meta-analysis inappropriate.
Conclusion: In children with cerebral palsy, there is moderate evidence that backward gait training improves balance, gross motor function, step length and walking velocity. More high-quality studies are needed.

Keywords
Backward walking, gait training, children, cerebral palsy, balance, systematic review

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Introduction
Balance deficits and gait limitations are common in children with cerebral palsy; gait training is an important part of their rehabilitation as it plays a major role in children’s quality of life and social participation. As cerebral palsy
cannot be cured; its treatment is increasingly focusing on improving activities, such as ambulation and self-care activities.\(^2\) The ultimate goal of rehabilitation in cerebral palsy is to enable the child to gain maximal functional independence by achieving the optimal developmental potential of the child.\(^3\)

For several decades, backward gait training has been used in sports to improve cardiovascular fitness and for prevention and rehabilitation of musculoskeletal injuries.\(^4,5\) It has been used not only with athletes but also with different populations as healthy non-athlete adults, elderly, and children.\(^6-9\)

Backward gait training was suggested to enhance stability and static balance for healthy adults and young women,\(^10,11\) also it found its place in the rehabilitation of patients with neurological disorders; it has been implemented in the gait training program to increase the motor control and improve the gait pattern of patients with stroke.\(^12\)

A narrative review of the literature was done in 2015 by Joshi et al.,\(^13\) about the role of retro-walking or backward gait training in physiotherapy and rehabilitation; it showed the limited evidence of retro-walking effect on balance and gait in children with cerebral palsy. Afterward, several studies\(^14-20\) suggested that backward gait training could be used in children with cerebral palsy.

This review aimed to investigate and summarize the most updated evidence on the effectiveness of backward gait training on balance, gross motor function and gait parameters in children with cerebral palsy.

### Method

This review was registered on PROSPERO register with a registration number CRD42017055559.

The databases PubMed, Cochrane Library, Web of Science, Science Direct, Physiotherapy Evidence Database (PEDro), and Google Scholar were searched without restrictions regarding language or year of publication. Relevant studies were also searched by the trial register ClinicalTrials.gov. The following keywords were used: “Backward,” “Rearward,” “Rear,” “Reverse,” “Gait,” “Walking,” “Locomotion,” and “Ambulation.” All databases were searched from the inception till May 2018.

Two independent reviewers (A.M.E. and S.E.) assessed titles and abstracts of the trials identified by the search against the eligibility criteria (Table 1). All articles that were considered potentially eligible were obtained in full text, and additional screening of reference lists of the eligible studies was also performed. A copy of the complete search strategy is included in Supplementary Appendix 1.

The quality of included studies was assessed using PEDro scale.\(^21\) Two authors (A.M.E. and M.G.A.) rated the included studied using PEDro scale, with any confliction resolved by the third author (S.E.).

The data extracted includes the participants’ age, gender, type and severity of cerebral palsy. Also, the intervention data include the device used, the training duration and frequency. The control intervention was no backward gait training while comparison intervention was forward gait training.
One reviewer (M.G.A.) extracted data from the included studies and a second reviewer (A.M.E.) cross-checked it. Continuous variables data were extracted and expressed as a mean difference with 95% confidence interval.22

The following classification was used for rating the methodological quality: a PEDro score of <4 indicated poor quality; score of 4–5 indicated fair quality; score of 6–8 indicated good quality; and score of 9–10 indicated excellent quality.23

For interpretation of results, Modified Sackett Scale was used to determine the level of evidence for each outcome.24

**Results**

The search strategy identified 1492 studies till May 2018. After screening titles and abstracts and removing duplicates, 38 full papers were retrieved. After assessing articles against the eligibility criteria, seven papers14–20 were included in the review (Figure 125; see Supplementary Appendix 1 for search strategy and the list of excluded studies).

Table 2 presented the summary of the included studies.26 The PEDro scores are presented in Table 3. From Table 2, we can summarize that there is clinical heterogeneity between the participants, interventions,
<table>
<thead>
<tr>
<th>Study</th>
<th>Participants</th>
<th>Intervention</th>
<th>Outcome measures</th>
</tr>
</thead>
</table>
| Abdou et al.\(^{14}\) | n = 30  
Mean age (range) = 6.1 years (5–7 years)  
Gender = not stated  
Classification = spastic hemiparesis, DDST  
12–17 months | Exp = backward gait training on treadmill 20 minutes, 3/week × 6 weeks  
Con = no intervention  
Both = regular PT program | Dynamic balance = mediolateral stability index via Biodex\(^{\circledR}\) balance system (°)  
Follow-up = 0, 3, 6 weeks |
| El-Basatiny and Abdel-aziem\(^{15}\) | n = 30  
Mean age (range) = 12 years (10–14 years)  
Gender = 16 M, 14 F  
Classification = spastic hemiparesis, GMFCS I–II  
12–17 months | Exp = backward gait training on ground based on methods as described by Davies and Klein-Vogelbach,\(^{26}\) 25 minutes, 3/week × 12 weeks  
Con = no intervention  
Both = traditional PT program | Dynamic balance = overall, anteroposterior & mediolateral stability indices via Biodex\(^{\circledR}\) balance system (°)  
Follow-up = 0, 12 weeks |
| Ayoub\(^{16}\) | n = 20  
Mean age (range) = 7.9 years (7–10 years)  
Gender = 7 M, 13 F  
Classification = spastic diplegia, GMFCS II–III | Exp = backward treadmill gait training with partial body weight support (30% relief of total body weight) using Biodex\(^{\circledR}\) unweighing equipment, 15 minutes, 3/week × 12 weeks  
Con = no intervention  
Both = regular PT program | Walking velocity using Biodex\(^{\circledR}\) gait trainer II (m/s)  
Follow-up = 0, 12 weeks |
| Ayoub\(^{17}\) | n = 20  
Mean age (range) = 7.9 years (8–11 years)  
Gender = 7 M, 13 F  
Classification = spastic diplegia, GMFCS II–III | Exp = Partial body weight supported backward treadmill training 15 minutes, 3/week × 12 weeks  
Con = Partial body weight supported forward treadmill training  
Both = regular exercise program | Step symmetry presented by time spent on each foot (% of gait cycle) using Biodex Gait Trainer 2\(^{\text{TM}}\)  
Follow-up = 0 |
Table 2. (Continued)

<table>
<thead>
<tr>
<th>Study</th>
<th>Participants</th>
<th>Intervention</th>
<th>Outcome measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abdel-aziem and El-Basatiny$^{18}$</td>
<td>$n = 30$ Mean age (range) = 12 years (10–14 years) Gender = 10 M, 20 F Classification = spastic hemiparesis, GMFCS I–II</td>
<td>Exp = backward gait training on ground based on methods as described by Davies and Klein-Vogelbach,$^{26}$ 25 minutes, 3/week $\times$ 12 weeks Con = forward gait training on ground 25 minutes, 3/week $\times$ 12 weeks Both = conventional PT program</td>
<td>Spatiotemporal gait parameters via 3D gait analysis system = step length (m), walking velocity (m/s), cadence (steps/minutes), percentage of the stance &amp; swing phases of the affected LL in relation to gait cycle (%) Activity = Dimensions D &amp; E of GMFM-88 (%) Follow-up = 0, 12, 16 weeks</td>
</tr>
<tr>
<td>Abdou$^{19}$</td>
<td>$n = 30$ Mean age (range) = not stated (5–7 years) Gender = not stated Classification = spastic diplegia, DDST 12–17 months</td>
<td>Exp = backward gait training on Treadmill, 20 minutes, 3/week $\times$ 6 weeks Con = no intervention Both = regular PT program</td>
<td>Dynamic balance = overall stability index via Biodex® balance system (°) Follow-up = 0, 6 weeks</td>
</tr>
<tr>
<td>Sanad$^{20}$</td>
<td>$n = 12$ Mean age (range) = not stated (5–9 years) Gender = 8 M, 4 F Classification = spastic diplegia, GMFCS I–III</td>
<td>Exp = Backward treadmill gait training 20 minutes, 3/week $\times$ 12 weeks Con = no intervention Both = traditional PT program</td>
<td>Walking speed using Biodex Gait Trainer 2TM Follow-up = 0</td>
</tr>
</tbody>
</table>

Exp: experimental group; Con: control group; RCT: randomized controlled trial; DDST: Denver Developmental Screening Test; GMFCS: Gross Motor Function Classification System; M: male; F: female; PT: physiotherapy; GMFM: Gross Motor Function Measure; LL: lower limb.
or outcome measures of the included studies. Therefore, meta-analysis was not applicable.

The quality of studies ranged from good (two studies15–18) to fair (four studies14,16,17,19) and poor (one study20), with a mean PEDro score of 4.7 out of 10 (range 3–7) (Table 3). Regarding the method of randomization and allocation, the lack of clarity was the main methodological limitation as whether randomization was achieved through software, random numbers or other methods, constituting high risk of bias. All the papers were randomized, analyzed the between-group difference, reported point estimates and variability. Most studies14,16,17,19,20 (71%) did not report <15% loss to follow-up, conceal the allocation list nor had blinded assessors. None of the studies carry out an intention-to-treat analysis, nor blind participants or therapists.

Participants were 172 children and adolescents who were classified as having either hemiparetic or diplegic cerebral palsy, including both genders and their ages ranged from 5 to 14 years.

Backward gait training was provided by treadmill without body weight support,14,19,20 by treadmill with body weight support16,17 or over ground,15,18 with a duration ranged from 15 to 25 minutes, three times a week and lasted from 6 to 12 weeks. The control group received either no backward gait training (five studies14–16,19,20) or the same dose of forward gait training (two studies17,18).

Measures of balance were reported in three studies,14,15,19 using the stability indices of Biodex® balance system. The levels of difficulty of stability testing was reported in only one study,15 but not mentioned in the other two studies.14,19

Measure of gross motor function was reported in one study.18 The measure chosen for the assessment of gross motor function was the Gross Motor Function Measure (GMFM-88).

Gait analysis was reported in four studies.16–18,20 The measures chosen for the analysis of gait were walking velocity,16,18,20 step length,18 cadence,18 and percentage of the stance phase in relation to gait cycle.17,18

The findings of the included studies are presented in Table 4. All the included studies showed
significant improvement in the measured outcomes. The clinical heterogeneity restricted the pooling of data from individual trials to determine a weighted estimate.

One high-quality study\textsuperscript{15} and two low-quality studies\textsuperscript{14,19} reported the effect of backward gait training on dynamic balance in children with cerebral palsy. Consequently, there is moderate-quality evidence (level 1b) to support using backward gait training to improve balance in children with cerebral palsy when compared to no intervention.

Two studies\textsuperscript{16,20} with low quality reported the effect of backward gait training on walking velocity in children with cerebral palsy when compared to control (no intervention). Consequently, there is limited evidence (level 2a) to support using backward gait training to improve walking velocity in children with cerebral palsy when compared to no intervention.

One high-quality study\textsuperscript{18} reported the effect of backward gait training on GMFM in children with cerebral palsy. Consequently, there is moderate-quality evidence (level 1b) to support using backward gait training to improve gross motor function in children with cerebral palsy when compared to same dose of forward gait training.

### Table 4. Mean (SD) of the post-treatment outcomes for each group and mean (95% CI) difference between groups of included studies.

<table>
<thead>
<tr>
<th>Study</th>
<th>Groups</th>
<th>Difference between groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Experimental group</td>
<td>Control group</td>
</tr>
<tr>
<td>Overall stability index (°)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>El-Basatiny and Abdel-aziem\textsuperscript{15}</td>
<td>1.4 (0.44)</td>
<td>1.8 (0.44)</td>
</tr>
<tr>
<td>Abdou\textsuperscript{19}</td>
<td>1.5 (0.28)</td>
<td>2.2 (1.3)</td>
</tr>
<tr>
<td>AP stability index (°)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>El-Basatiny and Abdel-aziem\textsuperscript{15}</td>
<td>1.1 (0.34)</td>
<td>1.4 (0.44)</td>
</tr>
<tr>
<td>ML stability index (°)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abdou et al.\textsuperscript{14}</td>
<td>1.1 (0.23)</td>
<td>1.6 (0.42)</td>
</tr>
<tr>
<td>El-Basatiny and Abdel-aziem\textsuperscript{15}</td>
<td>1.9 (0.51)</td>
<td>2.4 (0.65)</td>
</tr>
<tr>
<td>GMFM (dimension D) (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abdel-aziem and El-Basatiny\textsuperscript{18}</td>
<td>90 (6.4)</td>
<td>82 (7.1)</td>
</tr>
<tr>
<td>GMFM (dimension E) (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abdel-aziem and El-Basatiny\textsuperscript{18}</td>
<td>82 (13)</td>
<td>80 (13)</td>
</tr>
<tr>
<td>Walking velocity (m/s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ayoub\textsuperscript{16}</td>
<td>0.6 (0.12)</td>
<td>0.31 (0.14)</td>
</tr>
<tr>
<td>Abdel-aziem and El-Basatiny\textsuperscript{18}</td>
<td>0.53 (0.19)</td>
<td>0.46 (0.2)</td>
</tr>
<tr>
<td>Sanad\textsuperscript{20}</td>
<td>0.52 (0.16)</td>
<td>0.31 (0.14)</td>
</tr>
<tr>
<td>Cadence (steps/min)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abdel-aziem and El-Basatiny\textsuperscript{18}</td>
<td>122 (2.9)</td>
<td>126 (2.7)</td>
</tr>
<tr>
<td>Step length (m)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abdel-aziem and El-Basatiny\textsuperscript{18}</td>
<td>0.55 (0.16)</td>
<td>0.39 (0.13)</td>
</tr>
<tr>
<td>Stance phase percentage (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abdel-aziem and El-Basatiny\textsuperscript{18}</td>
<td>55 (1.7)</td>
<td>50 (1.6)</td>
</tr>
<tr>
<td>Ayoub\textsuperscript{17}(Left LL)*</td>
<td>46.7 (3.1)</td>
<td>43.7 (4.7)</td>
</tr>
<tr>
<td>Swing phase percentage (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abdel-aziem and El-Basatiny\textsuperscript{18}</td>
<td>44 (1.4)</td>
<td>49 (1.6)</td>
</tr>
</tbody>
</table>

SD: standard deviation; CI: confidence interval; GMFM: Gross Motor Function Measure; LL: lower limb.

*Backward gait training compared to same dose of forward gait training.
One high-quality study\textsuperscript{18} and one low-quality study\textsuperscript{17} reported the effect of backward gait training on gait parameters in children with cerebral palsy when compared to the same dose of forward gait training. Backward gait training improved walking velocity by 15%, cadence by 3%, step length by 41%, and stance phase percentage by 7%–9%. Consequently, there is moderate-quality evidence (level 1b) to support using backward gait training to improve gait parameters in children with cerebral palsy when compared to same dose of forward gait training.

Discussion

Results of all randomized controlled trials included in this review were consistent and agreed that backward gait training improve balance, gross motor functions, and gait parameters in children with cerebral palsy. The current review found moderate-quality evidence supporting the use of backward gait training for children with cerebral palsy.

Moderate evidence was reported from three studies\textsuperscript{14,15,19} that backward gait training improves balance. Several mechanisms have been suggested to explain the benefits of backward gait training for children with cerebral palsy; one of them was the reorganization of muscle synergies or neuromotor control in the lower extremities during backward gait training.\textsuperscript{9,27}

Backward gait training emphasizes on foot positioning behind the body that facilitates hip extension while the knee is going into flexion, instead of performing the crouched pattern of gait in which hip and knee are both in flexed position and the ankle is in dorsiflexion. It was stated that the neural and mechanical responses that based on the reduction in hip movement probably increases stability by minimizing the anterior–posterior displacement of the center of gravity, and shorter absolute swing/stance duration. The reversal of triple-flexion posture of the lower limbs and the improvement in postural balance were suggested as reasons for the improvement in the spatiotemporal gait parameters after backward gait training for children with cerebral palsy.\textsuperscript{6}

Another reported explanation was the greater muscle strength gain in the lower limbs during backward gait training that was attributed to the longer period of muscle activity when compared with forward gait training, also the sufficient practice opportunities was stated as an explanation for stability improvement in children with cerebral palsy who practiced backward gait training.\textsuperscript{18,28}

Findings of this review revealed limited evidence from two low-quality studies\textsuperscript{16,20} that backward gait training increases gait speed when compared to no intervention, while moderate evidence from one high-quality study\textsuperscript{18} was found that backward gait training improves gait parameters including walking velocity when compared to the same dose of forward gait training. Although results of the three studies\textsuperscript{16,18,20} were consistent that backward gait training improves gait speed, the present evidence is limited and not clear by considering also the heterogeneity between the inclusion criteria of the high-quality study\textsuperscript{18} with the other two studies\textsuperscript{16,20} and the method of training.

Studies in this review included children with cerebral palsy of hemiparetic type (Gross Motor Function Classification System (GMFCS) levels I and II)\textsuperscript{14,15,18} and diplegic type (GMFCS levels I to III).\textsuperscript{16,17,19,20}

Moderate evidence from one high-quality study\textsuperscript{18} was found that backward gait training improves gross motor function and gait parameters when compared to the same dose of forward gait training. Improvement in gross motor skills as standing and walking that involve upright posture was attributed to the improved neuromuscular control after backward gait training that overcomes the lower limbs extensor synergy pattern by repeated practicing of knee flexion combined with hip extension.\textsuperscript{12,18}

Various methods of backward gait training were used in the included studies, either training on the ground or using treadmill with or without body weight support. Both gait training on a stable or moving surface resulted in improved functional and static balance. However, gait training using treadmill resulted in a greater improvement of the functional balance in children with cerebral palsy.\textsuperscript{29} Backward treadmill training with partial weight support enhances walking abilities in children with...
cerebral palsy due to double impact of proper positioning of different body segments achieved by suspension along with improved balance and lower limb muscles strength gained by backward gait training. Backward gait training of any form is an intervention that does not allow blinding of the patients or the therapists; therefore, none of the included studies in this review blind the participated children or the therapists.

The main limitation of this systematic review is the low quality of included studies (mean PEDro score 4.7) which limit the strength of conclusion. In this review, the included studies lacked standardization in the method of backward gait training (technique and duration of walking), outcome measures, and follow-up. The duration of treatment varied between 15 and 25 minutes for a period of 6–12 weeks. Reassessment after the intervention also lack consistency; this clinical heterogeneity limits the degree of comparison between the results of these studies and makes meta-analysis inappropriate in the current review.

This review has provided a synthesis of randomized controlled trials that involved any form of backward gait training for children with cerebral palsy. There is moderate-quality evidence to recommend the use of backward gait training in the rehabilitation of children with cerebral palsy to improve balance, gait parameters, and gross motor functions. More well-designed studies on the effectiveness of backward gait training for children with cerebral palsy with larger sample sizes on different types of cerebral palsy and better methodology are still needed. Future high-quality research may confirm the present evidence about the benefit of backward gait training for children with cerebral palsy.

***Clinical messages***

- There is moderate evidence but no more that backward gait training improves mobility in children with cerebral palsy.
- There is some evidence that backward gait training may also improve balance and gross motor function in children with cerebral palsy.

Declaration of conflicting interests

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