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Effectiveness of backward walking training on spatial-temporal gait characteristics: A systematic review and meta-analysis

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ABSTRACT

Background: Backward walking training (BWT) is thought to affect gait biomechanics, but relevant evidence has been sparse and inconclusive.
Objective: This study systematically reviewed and quantified the effectiveness of BWT on spatial–temporal gait characteristics (STGC).
Methods: A keyword and reference search of interventions on BWT was conducted in five bibliographic databases: PubMed, Web of Science, SPORTDiscus, CINAHL, and Cochrane Library for articles published until November, 2017. Two reviewers independently screened titles, abstracts, and full texts of all articles and jointly decided the final pool. A standardized form was used to extract data from each included article. Meta-analysis was conducted to estimate the pooled effect of BWT on STGC.
Results: Eleven studies met the eligibility criteria and were included in the review. All studies reported some positive influences of BWT on STGC relative to forward walking training (FWT) and/or control. Compared to FWT, BWT was associated with an increase in forward gait speed by 0.69 (95% confidence interval [CI] = 0.12, 1.25) m/s and stride length by 0.51 (95% CI = 0.22, 0.80) cm. Compared to control, BWT was associated with an increase in forward gait speed by 1.00 (95% CI = 0.36, 1.64) m/s.
Conclusions: BWT could improve participants' STGC and be potentially useful in neurological rehabilitation. However, current evidence remains preliminary. The effects found could merely be due to differences in training intensity between the FWT and BWT, and thus, may not reflect actual differences between training in different walking directions. Future studies are warranted to elucidate the pathways linking BWT to gait biomechanics.

1. Introduction

Human gait is a fundamental ability in daily living (Kung, Fink, Legg, Ali, & Shultz, 2018). Gait performance is associated with specific cognitive changes and executive function, especially among older adults (Cohen, Verghese, & Zwerling, 2016), and compromised gait ability may predict cognitive decline and executive dysfunction (Abe et al., 2017; Lallart et al., 2014). In previous studies, gait characteristics were often used to assess locomotion performance, body movements, cognitive ability, and risk of fall (Coutts, 1999; Hobert et al., 2017; Maki, 1997; Studenski et al., 2011). Spatial-temporal gait parameters such as gait speed, cadence, stride length, and double support are key indicators for gait performance and health or disease status (Hodgins, 2008; Whittle, 2007).

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Gait speed may predict the incidence of fall, disability, and mortality in older adults (Menant, Schoene, Sarofim, & Lord, 2014; Perera et al., 2016), while step and stride length are considered as simple indicators of disease severity and reduced functional capability (Tramonti et al., 2017). Increased stride frequency during walking might help post-stroke individuals gain stability and reduce risk of fall (Hak et al., 2015).

Appropriately designed training programs may improve gait performance. Relevant interventions that were tested in previous studies include physical-cognitive dual task training (Falbo, Condello, Capranica, Forte, & Pesce, 2016), combined dual-task management with resistance training (Wollesen et al., 2017), dual-channel functional electrical stimulation (Springer, Laufer, Becher, & Vatine, 2013), and vibratory stimulation training (Park, Lim, & Song, 2015). Backward walking training (BWT) was recently introduced as a means for gait performance improvement (Grobbelaar, Venter, & Welman, 2017), and backward walking (BW) is thought to share similarities with forward walking (FW) but also has its own unique features (Suenaga, Hashizume, & Nishii, 2013). During BW, one has to rely more on senses rather than the visual system (e.g., auditory and sensory systems) because one does not have a complete view of the road and obstacles ahead. Regarding the motor control mechanism, BW and FW use the same rhythm circuitry, but BW in addition requires specialized control circuits (Hoogkamer, Meyns, & Duysens, 2014). Meanwhile, inter-limb locomotor coordination depends mostly on the coupling between spinal pattern generators, coordinated by brainstem mechanisms during BW and FW (Meyns, Molenaers, Desloovere, & Duysens, 2014). Unlike casual BW and FW, BWT and FWT have specific goals of improving one's performance by prescribing appropriate training frequency, intensity and duration, and focus on developing BW and FW skills. However, little is known regarding whether BWT affects gait biomechanics, especially spatial-temporal gait characteristics (STGC). This study is aimed to synthesize scientific evidence linking BWT to STGC and to quantify the relevant effect size. We hypothesize that BWT will improve key parameters of STGC including forward gait speed, cadence, stride length, and double support.

2. Methods

This review was conducted and reported in accordance with *Preferred Reporting Items for Systematic Review and Meta-analyses* (PRISMA) (Moher, Liberati, Tetzlaff, & Altman, 2009).

2.1. Study selection criteria

Studies that met all of the following criteria were included in the review: (1) Study design: intervention; (2) Participants: human; (3) Intervention component: BWT; (4) Outcomes: STGC parameters such as gait speed, cadence, stride length, and double support; (5) Time window of search: peer-reviewed articles published until November 16, 2017; and (6) Language: English.

Studies that met any of the following criteria were excluded from the review: (1) Conference proceeding, letter to editor, dissertation, or case report; (2) Review article; (3) Non-intervention study; and (4) Non-human study.

2.2. Search strategy

A keyword search was performed in five electronic bibliographic databases: PubMed, Web of Science, SPORTDiscus, CINAHL, and Cochrane Library. The search algorithm included all possible combinations of the keywords from the following two groups: (1) "walk*", "gait", "locomot*", "direct", "step", or "move*"; and (2) "backward". The four MeSH terms "gait", "walking", "locomotion" and "movement" were included in the PubMed search. All keywords in the PubMed were searched with the "[All fields]" tag, which are processed using Automatic Term Mapping (PubMed Help. National Center for Biotechnology Information (US)., 2017). The search function TS = Topic was used in Web of Science, SPORTDiscus, CINAHL, and Cochrane Library, which launches a search for topic terms in the fields of title, abstract, keywords, and Keywords Plus® (Advanced Search on EBSCO Interfaces., 2017; Cochrane Library. Search functionality available in the Cochrane Library. The Cochrane Library., 2017; EBSCOhost Research Databases., 2017; Web of Science Core Collection Help., 2017). Search algorithm in PubMed is reported in Appendix S1. Titles and abstracts of the articles identified through the keyword search were screened against the study selection criteria. Potentially relevant articles were retrieved for evaluation of the full text. Two reviewers, JW and WY, independently conducted title and abstract screening and identified potentially relevant articles. Inter-rater agreement was assessed using the Cohen's kappa ($\kappa = 0.83$). Discrepancies were resolved through face-to-face discussions between RA, JW and WY.

A reference list search (i.e., backward reference search) and a cited reference search (i.e., forward reference search) were conducted based on the full-text articles meeting the study selection criteria that were identified from the keyword search. Articles identified from the backward and forward reference search were further screened and evaluated using the same study selection criteria. Reference search was repeated on newly identified articles until no additional relevant article was found.

2.3. Data extraction

A standardized data extraction form was used to collect the following methodological and outcome variables from each included study: author, year of publication, country, sample size, age, sex, disease status, setting, intervention type, intervention dose, follow-up duration, intervention components, measures, key outcomes, other outcomes, statistical models, and estimated intervention effectiveness.