Comparing the effects of dual-task training and single-task training on walking, balance and cognitive functions in individuals with Parkinson's disease: A systematic review

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Abstract

Background: This systematic review aimed to examine whether dual-task (DT) training was superior to single-task (ST) training in improving DT walking, balance and cognitive functions for individuals with Parkinson's disease (PD).

Methods: Literature search was performed in the following electronic databases: PubMed, the Cochrane Library, Web of Science, and Metstr covering inception to May 10, 2023. And in order to facilitate comparison across trials, we calculated the effect size (Hedges' g) of gait, balance, cognitive, and other parameters under both ST and DT conditions, using the mean change score and standard deviation (SD) of change score of the experimental and control groups. Randomized controlled trials that examined the effects of DT motor and cognitive training in individuals with Parkinson's disease were included for this systematic review.

Results: A total of 214 participants recruited from six articles (actually five trials) were involved in this review. In terms of walking ability, only double support time and stride time variability showed significant between-group difference (Hedges' g = 0.34, 0.18, respectively). Compared to ST training group, DT training group had a more improvement effect in laboratory balance measurement (Hedges' g = 0.18, 1.25), but no significant improvement in clinical balance measurement. No significant between-group differences were observed, thus its training effect on cognitive function was inconclusive.

Conclusions: The DT training failed to achieve promising results better than ST training in improving DT walking and balance functions for individuals with PD. Any firm conclusion cannot be drawn at present, due to the limited number of eligible publications. Larger sample size and high-quality studies are needed to investigate the effectiveness of DT training in individuals with PD.

Keywords: Parkinson's disease; Dual-task training; Mobility; Cognition; Systematic review

Introduction

Parkinson's disease (PD) is the second most common central nervous system degenerative disease.[1,2] Motor deficits were observed in individuals with PD including postural instability and gait dysfunction.[3] Apart from motor symptoms, cognitive impairment is also common among individuals with PD.[4,5]

A variety of interventions have been used to alleviate the symptoms and improve functions of persons with PD.[2,5–7] Among them, walking and balance training are important rehabilitation methods to maintain and improve mobility function in individuals with PD.[6,7] However, in real-life scenarios, dual-task (DT) condition (i.e., performing two tasks simultaneously) is frequently encountered (e.g., talking to someone when walking). A typical DT testing paradigm includes a primary motor task (walking or standing) and a secondary attention-demanding task (cognition, e.g., serial subtractions, naming; or motor, e.g., holding a cup of water).[8] Under DT condition, degradation in the performance of one or both tasks (i.e., cognitive-motor interference) can be observed in many neurological disorders.[9–13] Similar to other neurological conditions,[14,15] more compromised DT balance and/or mobility performances are associated with increased risk of falls in persons with PD.[16]

Although decrements in DT performance are shown in individuals with PD, conventional rehabilitation has mainly focused on training balance or gait under single-task (ST) condition. In order to fully prepare individuals for community-living, improving their DT

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performance was thus of paramount importance.[17] Theoretically, DT performance could be improved by two approaches: (1) improving automaticity, i.e., ST training; (2) task-specific training, i.e., DT training.[9] However, controversy currently still exists as to whether DT training should be introduced to PD patients due to the notion that DT training may be fall-provoking in PD.[7]

In the past decade, a few systematic reviews and meta-analyses were published investigating the effects of DT balance and mobility training on individuals with PD.[18–20] However, any firm recommendation has not been made due to several important limitations. For example, studies with inferior study designs (e.g., lack of control group, historical controls) were included in the analysis.[18–20] The definition of DT training was not clear in some reviews.[18,19] Studies that involved comparison groups of very different nature were mixed in the same meta-analysis.[18,19] The results were thus very difficult to interpret because DT training may be superior to no-intervention controls, but not to other types of interventions. Thus, separate analyses are needed to determine the effects of DT training relative to different types of interventions so as to provide evidence to guide clinical practice.

To address the knowledge gap, the objective of this systematic review was to examine whether DT balance and/or mobility training was superior to ST training in improving walking, balance and cognitive functions under both DT and ST conditions for individuals with PD.

Methods

Search strategy

Literature search was performed in the following electronic databases: PubMed, the Cochrane Library, Web of Science, and Metstr from inception of the database to December, 2022. The keywords in the search strategy included: Parkinson disease, dual-task, balance, mobility, walking, etc. Details of the search strategy for the PubMed are provided in Supplementary Material, http://links.lww.com/CM9/B881. Similar strategies were used for other electronic databases. Article screening and selection were performed by two independent researchers (XYL, YMZ). References of selected articles were also screened to identify their potential relevance. Moreover, a forward search was conducted for all selected articles with the Web of Science to make sure that all eligible articles were included in this review. The last updated search was performed on May 10, 2023.

Eligibility criteria

The inclusion criteria were as follows. (1) Participants: adults with PD; (2) Intervention: the experimental group received DT balance and/or mobility training, with a detailed description of the training protocol provided; (3) Comparison: the comparison group received traditional ST balance and/or mobility training; (4) Outcomes: the primary outcomes were balance and gait performance in either the ST or DT conditions, while the secondary outcomes were cognitive function in either the ST or DT conditions, fall incidence, activity level, and participation level measures; and (5) Study design: randomized controlled trial.

The exclusion criteria was: the full text of the article was unavailable, despite contacting the authors.

Article selection

Two independent reviewers (XYL, YMZ) identified the potential relevance of the searched articles through screening their titles and abstracts. The eligibility of the article was then further determined by reading the full text. Disagreements between the two reviewers were resolved by discussing with the third reviewer (LY).

Assessment of methodological quality

The Ptysiotherapy Evidence Database (PEDro) score was used to assess the methodological quality of the included studies. Two studies were identified on the PEDro website (www.pedro.org.au).[21,22] For four publications that could not be searched on the PEDro website,[23–26] trained raters of PEDro team were requested to examine these four publications in duplicate via email.

Data extraction and synthesis

After reading the full text, the data were extracted and synthesized in the following aspects: characteristics of participants, training protocols, and outcome measurements. In order to better summarize the different kinds of outcomes, the gait parameters were divided into five categories, namely, pace (e.g., gait velocity and time taken to perform the timed up-and-go test), rhythm (e.g., cadence), postural control (e.g., step width, step length, and stride length), asymmetry (e.g., swing, stance, stance time, double support, and double support time), and variability (e.g., stride time variability),[26] while the cognitive outcomes were classified into four domains, namely, mental tracking, verbal fluency, reaction time, and working memory.[27] The balance outcomes were classified as either laboratory measures (e.g., center of pressure [COP]-related parameters), or clinical measures (e.g., Berg Balance Scale).[28] Due to the large heterogeneity of the identified publications, meta-analyses were not performed. However, to facilitate comparison across trials, we calculated the effect size (Hedges' g) of gait, balance, cognitive, and other parameters under both ST and DT conditions, using the mean change score and standard deviation (SD) of change scores of the experimental and control groups, if they were significant. The values of Hedges' g of 0.2, 0.5, and 0.8, were regarded as small, moderate, and large, respectively.

Results

Article selection and methodology assessment

A total of 495 publications were identified by the electronic database search. After eliminating the duplication, the articles were screened. Finally, six publications (actually five trials) fulfilled the eligibility criteria and were thus included in this review. The article selection flowchart is shown in Figure 1. The methodological quality of the included studies is summarized in Table 1. All studies were deemed to have good methodological quality as indicated by the PEDro scores (total scores: 6–8).

Participants' characteristics and training protocols

A total of 214 participants were involved. The severity of PD ranged from mild to severe, as indicated by the Hoehn and Yahr stages I–IV.[21–26] All participants in the control group underwent cognitive and motor training under ST condition, except in Fernandes *et al*[24] where only motor training under ST condition was implemented in the control group [Table 2].

Training time, frequency, and study duration ranged from 30 to 70 min per session, 2 to 3 times per week, and 4 to 10 weeks, respectively. DT training involved the practice of cognitive–motor tasks (five trials),[21–26] or motor–motor tasks (one publication) [Table 2].[23]

Changes over time within group

All reviewed studies reported significant improvements in a number of gait and balance outcomes over time in both the experimental and control groups [Tables 3 and 4],[21–23,25,26] with the exception of Fernandes *et al*[24] where the within-group comparisons before and after the training were not performed.

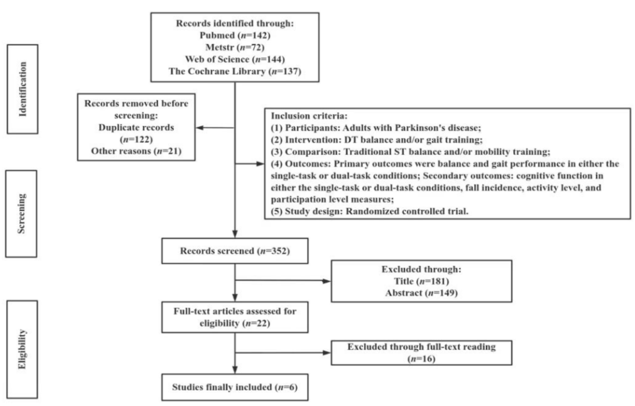

Figure 1: Flow chart of screening publications for comparing the effects of dual-task training and single-task training on walking, balance and cognitive function in individuals with Parkinson's disease. DT: Dual task; ST: Single task.

Comparison between DT and ST training groups

The between-group analyses presented in the reviewed studies provided the key to answer our review question, namely, whether DT training was superior to ST training.

Effects on walking ability

In six publications (five trials), the walking performance of both groups was compared under both ST and DT conditions [Table 3].[21–26] The gait-related parameters were synthesized as follows.

Pace: None of the studies showed significant between-group differences at post-intervention under either ST or DT conditions.[22–26]

Rhythm: None of the studies showed significant between-group differences in cadence at post-intervention under ST or DT conditions.[21–23,25]

Postural control: None of the studies showed significant between-group differences in step width, stride length or step length at post-intervention under ST or DT conditions.[21–23,25]

Asymmetry: Only double support time in cognitive DT training group showed significant greater improvement under cognitive DT condition (Hedges' $g = 0.34$).[23] Otherwise, no other measures (swing, stance, double support, double support base) demonstrated significant between-group differences at post-intervention under either ST or DT conditions.[21,23]

Variability: Greater improvement in stride time variability was only significant in the motor DT training group under motor DT condition, compared with the ST training group (Hedges' $g = 0.18$).[23] Otherwise, no significant between-group differences in stride time variability can be identified at post-intervention under ST conditions.[23]

Table 1: Physiotherapy Evidence Database (PEDro) scores of included articles.

Articles	Random allocation	Concealed allocation	Baseline comparability	Blind subjects	Blind therapists	Blind assessors	Adequate follow-up	Intention-to-treat analysis	Between-group comparisons	Point estimates and variability	Total scores	Methodological quality
Geroin *et al.*, 2018[21]	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	8	Good
San Martín Valenzuela *et al.*, 2020[22]	Yes	No	Yes	No	No	Yes	Yes	No	Yes	Yes	6	Good
Yang *et al.*, 2019[23]	Yes	Yes	Yes	No	No	Yes	No	No	Yes	Yes	6	Good
Fernandes *et al.*, 2015[24]	Yes	Yes	Yes	Yes	No	Yes	No	No	Yes	Yes	7	Good
Rosenfeldt *et al.*, 2019[25]	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	7	Good
Strouwen *et al.*, 2017[26]	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	8	Good

Table 2: Characteristics of adults with Parkinson's disease involved and training protocols.

Studies	Characteristics of participants				Training protocols		
	*Sample size (proportion of female)	Age (mean [SD], or median [interquartile range]) (years)	Disease duration (years)	Hoehn -Yahr stages	Training volume	Dual-task training group	Single-task training group
Geroin *et al.*, 2018[21]	121 (27.3%) DTG: n = 56 STG: n = 65	DTG: 65.80 (9.19) STG: 66.05 (9.30)	DTG: 8.41 (5.29) STG: 8.89 (6.30)	II–III	(40 min + 30 min) × 2 times/week × 6 weeks	30 min: gait practice + cognitive exercises 10 min: functional training 30 min: gait training and mental practice using a music player	15 min gait practice, 15 min cognitive exercises in sitting and 10 min functional practice 30 min gait training and mental practice using a music player
San Martín Valenzuela *et al.*, 2020[22]	40 (42.5%) DTG: n = 23 STG: n = 17	DTG: 66.38 (7.06) STG: 64.75 (8.77)	DTG: 6.33 (5.99) STG: 5.25 (3. 81)	I–III	60 min ×2 times/week ×10 weeks	First part: consecutive-task training (walking and cognitive or motor arm tasks) + second part: progressive dual-task training (gait training + cognitive training)	10 min of warm-up exercises 45 min of gait training 5 min cool-down with self-assisted stretching
Yang *et al.*, 2019[23]	18 (33.4%) DTG: n = 12 STG: n = 6	CDTT: 65.0 (57.5, 75.8) MDTT: 69.5 (65.0, 77.0) STG: 66.5 (55.5, 76.5)	CDTT: 5.5 (2.8, 10.5) MDTT: 5.0 (0.1, 12.5) STG: 3.0 (0.3, 10.0)	I–III	30 min × 3 times/week × 4 weeks	CDTT: cognitive tasks + walking tasks MDTT: motor tasks + walking tasks	15 min general gait training 15 min treadmill training
Fernandes *et al.*, 2015[24]	15 (26.7%) DTG: n = 7 STG: n = 8	DTG: 63.4 (9.5) STG: 62.3 (12.9)	DTG: 8.8 (4.3) CON: 7.7 (7.5)	I–III	60 min × 2 times/week × 6 weeks	Motor tasks + cognitive tasks	Motor tasks
Rosenfeldt *et al.*, 2019[25]	20 (30.0%) DTG: n = 10 STG: n = 10	DTG: 59 (9) STG: 65 (8)	DTG: 8 (4, 12) STG: 4 (3, 6)	II–IV	45 min × 3 times/week × 8 weeks	Gait training + cognitive training	Gait training and cognitive training separately (gait training, 22.4 ± 3.1 min/session, and cognitive training, 22.1 ± 0.1 min/session)
Strouwen *et al.*, 2017[26]	121 (27.3%) DTG: n = 56 STG: n = 65	DTG: 65.80 (9.19) STG: 66.05 (9.30)	DTG: 8.41 (5.29) STG: 8.89 (6.30)	II–III	(40 min + 30 min) × 2 times/week × 6 weeks	30 min: gait practice + cognitive exercises 10 min: functional training 30 min: gait training and mental practice using a music player	15 min gait practice, 15 min cognitive exercises in sitting and 10 min functional practice 30 min gait training and mental practice using a music player

*Since the population enrolled in Geroin *et al* and Strouwen *et al* was the same with the same intervention, therefore, 121 patients were removed. CDTT: Cognitive dual-task gait training; CON: Control group; DTG: Dual-task group; MDTT: Motor dual-task gait training; SD: Standard deviation; STG: Single-task group.

Effects on balance function

Three publications (three trials) assessed the clinical and laboratory balance outcomes, which were all measured under ST condition [Table 3].[23,24,26]

Clinical measures: No significant between-group differences in fall incidence rate and fall efficacy were observed after intervention.[23,26]

Laboratory-based measures: Only one study investigated the difference of COP-related parameters (sway, velocity) after intervention.[24] Significant better improvement in COP sway in the mediolateral (COPx, Hedges' g = 0.18) and anteroposterior (COPy, Hedges' g = 1.25) direction in the DT training group, compared with the ST training group, was observed when eyes were closed. However, when eyes were open, the difference in COP sway (COPx or COPy) was not significant. The total velocity of COP showed no significant differences regardless of whether the eyes were open or closed.[24]

Effects on cognitive function

Four publications (four trials) compared different domains of cognitive performance between the two training groups at post-intervention under both ST and DT conditions [Table 4].[22,24–26] No significant between-group differences were observed at post-intervention, under either ST or DT conditions.

Table 3: Effects on mobility and balance outcomes comparison of involved patients with Parkinson's disease.

	Within-group comparison				Between-group comparison	
	Under single-task condition		Under dual-task condition			
Outcomes	Dual-task training group	Single-task training group	Dual-task training group	Single-task training group	Under single-task condition	Under dual-task condition
Mobility outcomes (n = 5)						
Pace	Speed Post-intervention: *[22, 25, 26]; CDTT: *[23]; MDTT: (NS)[23] TUG time Post-intervention: CDTT: *[23] ; MDTT: (NS)[23]	Speed Post-intervention: *[22]; (NS)[22, 23] TUG time Post-intervention: (NS)[23]	Speed Post-intervention: *[22, 25, 26]; CDTT: *[23]; MDTT: (NS)[23]	Speed Post-intervention: *[22, 25, 26]; (NS)[23]	Speed Post-intervention: (NS)[22, 23, 25] TUG time Post-intervention: (NS)[23, 24]	Speed Post-intervention: (NS)[22, 23, 25, 26]
Rhythm	Cadence Post-intervention: *[18]; (NS)[25]; CDTT: *[23]; MDTT: (NS)[23]	Cadence Post-intervention: *[18]; (NS)[23, 25]	Cadence Post-intervention: *[18]; (NS)[22, 25]; CDTT: (NS)[23]; MDTT: *[23]	Cadence Post-intervention: *[18]; (NS)[23, 25]	Cadence Post-intervention: (NS)[22, 23, 25]	Cadence Post-intervention: (NS)[21–23, 25]
Postural control	Step width Post-intervention: *[23]; (NS)[22, 25] Step length Post-intervention: *[25] Stride length Post-intervention: *[21, 22]; (NS)[23]	Step width Post-intervention: *[25]; (NS)[22] Step length Post-intervention: *[25] Stride length Post-intervention: *[21]; (NS)[22, 23]	Step width Post-intervention: (NS)[22, 25] Step length Post-intervention: *[25] Stride length Post-intervention: *[21, 22]; CDTT: *[23]; MDTT: (NS)[23]	Step width Post-intervention: *[25]; (NS)[22] Step length Post-intervention: *[25] Stride length Post-intervention: *[21, 22]; (NS)[23]	Step width Post-intervention: (NS)[22, 25] Step length Post-intervention: (NS)[23, 25] Stride length Post-intervention: (NS)[22]	Step width Post-intervention: (NS)[22, 25] Step length Post-intervention: (NS)[21, 23, 25] Stride length Post-intervention: (NS)[22]
Asymmetry	Swing/Stance/Double support Post-intervention: *[21] Double support time Post-intervention: CDTT: *[23]; MDTT: (NS)[23]	Swing/Stance/Double support Post-intervention: *[21] Double support time Post-intervention: (NS)[23]	Swing/Stance/Double support Post-intervention: *[21] Double support time Post-intervention: CDTT: *[23]; MDTT: (NS)[23]	Swing/Stance/Double support Post-intervention: *[21] Double support time Post-intervention: (NS)[23]	Double support time Post-intervention: (NS)[23]	Swing/Stance/Double support Post-intervention: (NS)[21] Double support base Post-intervention: (NS)[21] Double support time Post-intervention: CDTT: 0.34*[23]; MDTT: (NS)[23]
Variability	Stride time variability Post-intervention: CDTT: *[23]; MDTT: (NS)[23]	Stride time variability Post-intervention: (NS)[23]	Stride time variability Post-intervention: *[21]; CDTT: *[23]; MDTT: (NS)[23]	Stride time variability Post-intervention: *[21] (NS)[23]	Stride time variability Post-intervention: (NS)[23]	Stride time variability Post-intervention: CDTT: (NS)[23]; MDTT: 0.18*[23]
Balance Outcomes (n = 3)						
Clinical Outcome Measure	–	–	–	–	Falls incidence rate Post-intervention: (NS)[26] Fall efficacy Post-intervention: (NS)[23]	
Laboratory Outcome Measure (all under single-task condition)	–	–	–	–	COPx Post-intervention: Eye open: (NS)[24]; Eye closed: 0.18*[24] COPy Post-intervention: Eye open: (NS)[24]; Eye closed: 1.25*[24] The total velocity Post-intervention: (NS)[24]	

*Significant within- or between-groups differences. CDTT: Cognitive dual-task gait training; COPx: The mediolateral direction of center of pressure; COPy: The anteroposterior direction of center of pressure; MDTT: Motor dual-task gait training; n: Number of included studies; NS: Not significant; TUG: Timed Up and Go test; –: Not reported.

Table 4: Effects on cognitive and other outcomes comparison of involved patients with Parkinson's disease.

Outcomes	Within-group comparison: Under single-task condition: Dual-task training group	Within-group comparison: Under single-task condition: Single-task training group	Within-group comparison: Under dual-task condition: Dual-task training group	Within-group comparison: Under dual-task condition: Single-task training group	Between-group comparison: Under single-task condition	Between-group comparison: Under dual-task condition
Cognitive function	Reaction time Post-intervention: (NS)[22, 25]	Reaction time Post-intervention: *[22]; (NS)[25]	Reaction time Post-intervention: *[22, 25, 26]	Reaction time Post-intervention: *[22, 25, 26]	Reaction time Post-intervention: (NS)[22, 24, 26]	Mental tracking Post-intervention: (NS)[25]
	Mental tracking Post-intervention: (NS)[25]	Mental tracking Post-intervention: (NS)[25]	Mental tracking Post-intervention: *[25]	Mental tracking Post-intervention: *[25]	Mental tracking Post-intervention: (NS)[25]	Working memory Post-intervention: (NS)[25]
	Working memory Post-intervention: (NS)[25]	Working memory Post-intervention: (NS)[25]	Working memory Post-intervention: (NS)[25]	Working memory Post-intervention: (NS)[25]	Working memory Post-intervention: (NS)[25]	Verbal fluency Post-intervention: (NS)[25]
	Verbal fluency Post-intervention: (NS)[25]	Verbal fluency Post-intervention: (NS)[25]	Verbal fluency Post-intervention: (NS)[25]	Verbal fluency Post-intervention: (NS)[25]	Verbal fluency Post-intervention: (NS)[25]	
Other outcomes	UPDRS-part III Post-intervention: *[25]				UPDRS-part III Post-intervention: (NS)[24–26]	
	Freezing of gait questionnaire Post-intervention: CDTT: (NS)[23]; MDTT: *[23]; Single-task group: (NS)[23]				Freezing of gait questionnaire Post-intervention: (NS)[23]	
	PDQ-39 Post-intervention: Experimental group: *[22]; Single-task group: (NS)[22]				PDQ-39 Post-intervention: (NS)[23]	

*Significant within-group differences. Reaction time includes rule shift cards test, trail making tests A and B, reaction time stroop, reaction/response time digit span; mental tracking includes serial 7 responses, serial 7 correct; working memory includes digit recall. CDTT: Cognitive dual-task gait training; NS: Not significant; PDQ-39: Parkinson's Disease Questionnaire-39; UPDRS-part III: Unified Parkinson's Disease Rating Scale part III.

Effects on other outcomes

Five publications (five trials) examined the training effects on the changes of the Unified Parkinson's Disease Rating Scale part III (UPDRS-part III) score, freezing of gait questionnaire, and Parkinson's Disease Questionnaire-39 (PDQ-39) [Table 4].[22–26] No significant between-group differences in these outcomes were identified at post-intervention.

Adverse events and attrition

No adverse was reported during training in any of the included studies. The attrition was not reported in three studies.[23–25] The other three studies showed attrition rates ranging from 9.9% to 16.7%.[21,22,26]

Discussion

A total of six publications (five trials) were included in this review, comparing the effects of DT training with ST training on walking, balance, cognitive, and other functions in individuals with PD. Compared with pre-intervention, although DT training may improve gait (pace, rhythm, postural control, asymmetry, variability), balance (fall incidence, mediolateral and anteroposterior sway in closed-eye tests), cognition, and other outcomes (UPDRS-part III score, freezing of gait questionnaire, PDQ-39), most studies showed no significant between-group differences under either DT or ST conditions. In addition, the evidence was provided by insufficient trials, making it impossible to make any firm conclusions.

Previous reviews concluded that people with mild to moderate PD would benefit from DT training,[18–20] based on the comparisons with studies that had either no control group or no-intervention controls.[16,29–31] This is in line with the results of the majority of studies reviewed here in that DT training itself led to significant improvement in a variety of outcomes (i.e., within-group analysis). However, our research question is whether DT training was superior to ST training. According to our between-group analysis, the DT training effects on walking, balance, cognitive, or other functions under either DT or ST conditions were largely similar to the ST group, although the DT group showed better results in a few outcome measures including double support time and stride time variability under DT condition,[23] and COPx when eyes were closed under ST condition.[24]

As the previous theories proposed, the DT ability may be improved due to task-specific training (i.e., by DT training) or improvement in automaticity of movement (i.e., by ST training).[32,33] Since studies in our review all showed significant and largely similar improvements over time in both DT and ST training groups, we postulate that the DT ability could be improved through both mechanisms in people with PD.

In terms of balance function, the training effects on laboratory measures (COP-related parameters) were investigated all under ST condition. Although significant between-group differences were observed in the mediolateral and anteroposterior sway when eyes were closed, the results were generated by one study only,[24] and were thus inconclusive.

No significant differences in the number and frequency of falls were observed in individuals with PD before and after treatment, regardless of the ST training or DT training.[23,26] This is quite different from Pang *et al*[34] which demonstrated that the DT training program was more effective than the ST training program in reducing the risk of falls and fall-related injuries in individuals with chronic stroke. This could be attributed to the small sample size (only six in each group)[23] and relative short follow-up period (12 weeks)[26] in the reviewed studies. By contrast, in Pang *et al*'s study[34] the sample size and follow-up period were 84 participants with chronic stroke and 6 months, respectively. It is also possible that the different disease (stroke *vs*. PD) accounts for the different DT training effect in reducing the risk of falls. Therefore, the exact mechanisms of DT training in falls prevention in different patient populations need to be further investigated.

None of the cognitive outcomes were significantly changed at post-intervention.[22,24–26] The reliability of cognitive outcome measures is generally lower than that of the gait outcomes.[35–37] Because of the greater inherent variability of cognitive measures, a greater change in scores is needed to produce significant results. Perhaps more intensive or longer training is needed to induce a significant between-group difference.

None of the reviewed studies examined the factors associated with better treatment outcomes. Because of the relatively few studies included in this review, we were unable to perform meta-regression to identify the determinants for successful treatment outcomes. The literature may shed some light on the potential determinants of treatment success. In their secondary analysis, Strouwen *et al*[38] demonstrated that lower DT walking speed and higher cognitive ability (Scales for Outcomes in Parkinson's Disease-Cognition) at baseline are determinants of better improvements in DT walking speed after DT training in PD. As DT training is a form of exercise training, exercise behavior of the participants may also be a potential influencing factor. In a questionnaire survey and a semi-structured interview, Zaman *et al*[39] showed that male was one of the positive predictors of exercise whereas fear of falling was one of the negative predictors in individuals with PD. Perhaps sex of the participants and degree of fear of falling could be potential determinants of successful treatment outcomes. Future research on how these different factors impact treatment outcomes is warranted.

Clinical and research implications

This review has important implications for healthcare professionals. First, no adverse events during training were reported in the included studies, indicating the feasibility of incorporating DT training into rehabilitation programs for individuals with PD. Second, as a training method much closer to real-life scenarios, findings of this review may provide the basis for creating exercise programs that address DT performance for individuals with PD, and should merit more attention of healthcare professionals and researchers. There are a number of implications for researchers as well. This review has identified a number of knowledge gaps that warrant further research. Future studies should include the assessment of gait, balance and cognitive outcomes in both ST and DT conditions. In addition, it is important to include falling rate, physical activity level, and societal participation as outcomes, so that the impact of DT training can be more comprehensively studied. It is also important to compare the effects of different DT training protocols so that the optimal DT training strategy can be identified for individuals with PD. In addition, future research should explore the determinants for successful treatment outcomes.

Limitations

Although the design of randomized controlled trials was used in all included studies, the sample size of most studies was small. Three publications involved less than 20 participants, which would reduce the statistical power to detect significant changes between groups and the generalizability of the studies.[23–25] Furthermore, the retention of training effects was documented in four publications,[21,22,25,26] while the other two publications did not report them.[23,24] These factors have limited our understanding of the effectiveness of DT training in individuals with PD. More well-designed, larger sample size randomized controlled trials are needed to compare the effectiveness of DT training for patients with PD.

As to limitations of our review, the articles reviewed were published in English only. Some relevant research published in other languages might have been missed. This may potentially reduce the comprehensiveness of the results. For the same reason, the generalizability of the results may be limited to those countries where English was used to disseminate research findings. Because of the heterogeneity of the reviewed studies, meta-analysis was not conducted. As the objective of this study was to determine whether DT training was better than ST training, only those randomized controlled trials that compared between DT training and ST training were included. The benefits of DT training compared with other intervention or no-intervention were not investigated.

Conclusions

DT training improved various gait and balance functions in individuals with PD. With the exception of a few outcomes, the degree of improvement induced by DT and ST training were largely similar. Thus, there was insufficient evidence showing that DT training was superior to ST training. Any firm conclusion cannot be drawn at present; current findings need to be interpreted with caution, due to the limited number of eligible publications. Larger sample size and high-quality studies are needed to investigate the effectiveness of DT training in individuals with PD.

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Conflicts of interest

None.

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