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REVIEW

Effects of dual-task interventions on gait performance of patients with Parkinson's Disease: A systematic review

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OBJECTIVE: Parkinson's disease is characterized by motor and non-motor symptoms that impair patients' gait performance, especially while performing dual/concurrent tasks. These deficits impair patients' daily function, because dual-tasking is a crucial ability in terms of everyday living. The aim of this study was to systematically review the effects of dual task interventions on gait performance of patients with Parkinson's disease.
METHOD: Studies were retrieved from MEDLINE/PubMed, LILACS and SciELO. We used the PICOS strategy to determine eligibility criteria. The search strategy included an advanced search on the included databases, using the following search query: "Parkinson's Disease" AND "Double Task" OR "Concurrent Tasks" OR "Gait" AND "Walk". Study selection was carried out by two independent researchers and a third one was called when consensus was needed.
RESULTS: A total of 188 articles were identified: 169 articles from Medline/PubMed, 10 articles in SciELO, 8 articles in LILACS and 1 item from manual searches. A total of 56 articles were analyzed regarding the eligibility and exclusion criteria based on full text. A final total of 7 studies were included in the systematic review.
CONCLUSION: The different types of dual-task interventions reported (dance, sound stimuli, visual and somatosensory) were associated to improvements in several gait performance indicators of Parkinson's disease patients, including gait speed, stride time and length, cadence and step length. External stimuli seem to play a critical role on specific training effects on dual-task gait performance.

KEYWORDS: Parkinson's disease, dual-task, gait.

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INTRODUCTION

Parkinson's disease is the second most common neurodegenerative disease, only falling short to Alzheimer's disease.[1] There are an estimated 4 million people with PD across the world and the number of diagnosed patients may double by 2030.[2]

Parkinson's disease is a neurologic, neurodegenerative and chronic illness which hinders the central nervous system and specially targets the basal ganglia. The disease is characterized by a preferential loss of dopaminergic neurons located in the pars compacta of the substantia nigra, by a reduction of dopamine levels in the striatum and by intracellular protein inclusions (Lewy bodies).[3] Motor symptoms are the main focus of PD with patients displaying bradykinesia, stiffness, tremor and postural instability.[3] Patients also show non-motor symptoms which can be categorized as sensory, autonomic and cognitive-behavioral, such as depression, apathy, anxiety, psychosis and dementia.[4] With disease progression, there is a decline in the ability of patients to perform activities of daily living, a loss of independence

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and a decreased quality of life, all of which lead to impaired occupational functioning and increased socioeconomic costs.

In daily life the performance of simultaneous tasks such as walking while making a phone-call and monitoring the world around us is a clear advantage and even a requirement to the leading of a normal life. Under normal circumstances, concomitantly performing motor and cognitive tasks is common, as motor activities are almost "automatically" performed and do not require conscious attentional resources.[5] Dual-task (DT) performance is also known as simultaneous performance as it implies the primary execution of a task which is the main focus of attention and a second task, which is completed at the same time. Simultaneous performance of cognitive and motor tasks during walking tipically changes gait patterns.[6] Some studies have demonstrated that PD patients have impaired equilibrium and gait in DT conditions when compared to age-matched controls.[7,8] The interference of DT on PD is frequently associated with reduced gait speed as well as step asymmetry, variability and length.[8] Increased step variability during DT is associated to reduced executive functioning.[9]

In PD patients, the automaticity promoted by basal ganglia is compromised and it becomes necessary to consciously control gait.[10,11] When patients are performing concurrent tasks, the frontal regions focus on the secondary task while gait is controlled by the impaired basal ganglia, leading to a negative interference of DT on walking performance.[11,12]

Gait impairment and walking disturbances are common in patients with PD. While gait anomalies are not pronounced in early stages of the disease, their prevalence and severity increases as the disease progresses.[13] Patients with PD also display several movement deficits during DTs, including postural control,[8,12,14] upper limb movements [8,15,16] and speech,[9,17] while gait impairments are accentuated.[8]

There are several alternatives to explain this interference and the bottleneck theory is well-known. When two tasks are performed simultaneously and engage the same neural processes/networks this creates a functional "bottleneck", causing a delay in one of the tasks until those neural processes/networks can be recruited again. Thereby, it is not possible to simultaneously execute tasks which rely on similar neural networks in the brain.[18] The resource sharing model is based on the argument that the brains' attentional resources are limited. This means that during the execution of simultaneous tasks neural resources should be divided among them. However, an interference with dual tasking may occur when the capacity of these attentional resources is exceeded, hindering performance on one or both of the tasks.[10,19]

Another possible explanation for the negative interference of DT on gait performance in PD patients may lie in the impairment of cognitive executive function, with a putative role of attention and working memory. According to this theory, gait pattern during DT would not be compromised by attentional resource limitations; the underlying problem would be executive dysfunction and the reduced ability of PD patients to manage multiple tasks.[17]

The goal of our study was to systematically review the literature regarding the effects of several DT interventions upon gait performance of PD patients. The effects of DT interventions and training programs suggest that gait improvements in PD patients is possible.

METHOD

Eligibility Criteria

We used the PICOS strategy (population, intervention, comparators, results and study design) to determine eligibility:

1. Population: adults or elderly with PD, according to the criteria of the Parkinson's Disease Society Brain Bank of the United Kingdom.[20] Participants could be in "OFF" or in "ON" medication periods.
2. Intervention: assessed DT interventions using motor and cognitive tasks.
3. Comparators: Control groups comprising either PD patients as an active control group or without any kind of intervention.
4. Results: Motor indicators related to patients' gait performance such as gait/walking speed, stride length and time, step length and cadence (steps per minute) or other standardized assessment procedures to assess gait.
5. Study Design: randomized and non-randomized controlled trials which assessed the effects of DT on gait performance of PD patients.

Exclusion Criteria

We excluded studies which: (a) did not include a control group or that included a control group without PD patients; (b) did not include an intervention effectively addressing DT; (c) included other interventions combined with DT which could enhance risk of bias; (d) included patients with other neurologic disorders; (e) did not appropriately describe statistical procedures; (f) did not report specific outcomes related to gait.

Sources

We systematically searched for appropriate studies using MEDLINE/Pubmed, SciELO and LILACS setting December 31, 2015 as the date limit. Experts on the topic were contacted to suggest relevant studies. Included trials and previous systematic reviews references were also manually screened for additional relevant studies.

Search Strategy

The search was performed using an advanced search on MEDLINE/Pubmed, LILACS and SciELO databases with the following key-words selected: "Parkinson's disease" AND "Dual-Task" OR Concurrent Tasks" AND "Gait" OR "Walking". All the necessary search combinations were applied to the databases.

Study Selection

Study selection was performed by two independent evaluators. Consensus regarding selected articles was established based on eligibility criteria. A third rater was called to address any disagreements between the raters. After database searching, the reports were firstly screened based through title and abstract; studies were excluded if they clearly did not met eligibility criteria. Relevant articles were obtained and assessed for eligibility criteria described in the methods.

Data Extraction

For each included study, the following data was extracted: sample size, patients' characteristics (age, stage and duration of the disease, ON/OFF medication), DT intervention characteristics (modality, exercise time and total length), gait outcomes and main significant findings (group by time or time by task interactions and within group changes).

RESULTS

A total of 188 records were identified on the initial search: 169 from MEDLINE/Pubmed, 10 from SciELO, 8 from LILACS and 1 from manual search. After removing duplicates (*n* = 97), 91 articles remained. After title and/or abstract analysis 35 papers were excluded as they did not address the aim of the review. The remaining 56 papers were analyzed according the predefined eligibility and exclusion criteria. A total of 7 studies were included in this systematic review (Figure 1).

Information regarding the participants' and intervention characteristics from the included studies as well major findings on gait performance are reported in Table 1. In the included studies the only instrument used to assess the stage of the disease was the *Horn & Yahn Scale*.[21] For gait related outcomes, the following parameters were reported across studies: gait speed, step length, stride time and length, cadence (steps per minute), walking with pivot turns, *Freezing* Gait Questionnaire (FoG_Q),[22] Six Minutes Walking Test (6MWT),[23] Timed Up and Go (TUG) and Timed Up and Go-Dual Task (DT-TUG).[24]

Every PD patient completed the assessment and intervention procedures during the ON medication period, with exception of those in two studies in which patients

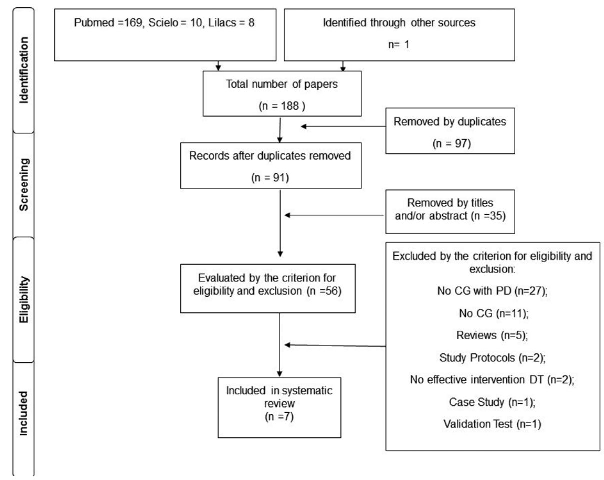

Figure 1. A representation of the PICOS procedure as employed for this review.

were enrolled in the intervention ON medication, but evaluated during the OFF medication period.[25,26]

All the included studies reported some sort of improvement on gait related outcomes, whether significant findings regarded gait speed, stride length and time, step length, cadence or even performance on standardized measures (e.g. TUG). However, DT training and assessing procedures were quite diverse across studies which made findings difficult to compare. Thereby, the reports were grouped and sub analyzed accordingly to similarities between the selected interventions methodologies.

Dual-Task: Dancing

Dancing is a type of exercise that challenges the balance and gait of PD patients. Challenges to dynamic balance are often incorporated into dancing, so that the user can get used to a changing environment while moving.[27] We found three articles [25,26,28] that compared an argentine tango dancing group to a control group which underwent an active control intervention.

The study by Romenets et al.[28] lasted 12 weeks, with one hour sessions twice a week and included a total of 33 PD patients (Tango = 18; Control = 15). There were no significant between-group differences at baseline in age, gender, levodopa dosage, disease duration and severity, although control participants were more likely to exercise regularly and have a history of falls in the last 12 months. Regarding gait performance, the tango group exhibited significant improvements in TUG and DT-TUG performance in comparison to the control group, with findings trending toward significance regarding walking with pivot turns. There were no significant interactions regarding DT-TUG time and Freezing on Gait Questionnaire (FoGQ) score.

Duncan & Earhart[25,26] published two articles regarding a 24 month clinical trial using Tango dancing. During the first year[25], 62 patients (Tango = 26; Control =

Table 1. General characteristics of seven studies included in this systematic review

Study/ Year	Sample Size Age	PD Stage (H&Y)/PD Duration (years)	Medication	Treatment & Assessment Procedures	Type of DT	Measures	Main results
Romenets et al.[28]	n = 33 TDG = 18 63.2 ± 9.9 CG = 15 64.3 ± 8.1	1 - 3 TDG 5.5 ± 4.4 CG 7.7 ± 4.6	ON	TDG: Tango Dance, 60' group sessions, 2 times per week, during 12 weeks. CG: Daily home-based exercises.	Tango Dance	TUG (sec) DT-TUG score Walking with pivot turns	Significant group x time interaction ($p = 0.042$); TDG ↑ in comparison to CG. Significant group x time interaction ($p = 0.012$); TDG ↑ in comparison to CG. Non-significant trend group x time interaction ($p = 0.066$); TDG ↑ in comparison to CG.
Duncan & Earhart[25]	n = 52 TDG = 26 69.3 ± 1.9 CG = 26 69.0 ± 1.5	TDG=1-4 5.8 ± 1.1 CG = 2-4 7.0 ± 1.0	ON during intervention OFF during assessments	TDG: Tango Dance, 60' group sessions, 2 times per week, during 24 months. CG: No prescribed exercise. Assessment: Baseline, 3, 6 and 12 months.	Tango Dance	FoGQ Gait Speed 6MWT	Significant group x time interaction ($p = 0.006$); TDG maintained performance while CG ↓ after 12 months. Significant group x time interaction for forward walking ($p = 0.04$) and DT walking ($p = 0.02$); TDG ↑ in comparison to CG at 6 and 12 months. Significant interaction ($p = 0.02$); TDG maintained performance while CG ↓ after 12 months.
Duncan & Earhart[26]	n = 10 TDG = 5 69.6 ± 6.6 CG = 5 66 ± 11	TDG = 2-3 6.6 ± 7.5 CG = 2-2,5 11 ± 3.9	ON during intervention OFF during assessments	TDG: Tango Dance, 60' group sessions, 2 times per week, during 24 months. CG: No prescribed exercise. Assessment: Baseline, 12 and 24 months.	Tango Dance	DT-TUG 6MWT	Significant group x time interaction ($p = 0.048$); TDG ↑ in comparison to CG, although there were no significant between group differences at any time point. Significant group x time interaction ($p = 0.013$); TDG maintained performance while CG ↓ after 24 months.
de Bruin et al.[29]	n = 22 MG = 11 64.1 ± 4.2 CG = 11 67.0 ± 8.1	MG = 2-3 6.4 ± 4.2 CG = 2-2.5 4.5 ± 3.3	ON	MG: 30' walking at a comfortable pace, while listening self-selected music, 3 times per week, during 13 weeks. Patients also performed their regular activities. CG: continued their usual routine during 13 weeks. Both groups reported daily activities and eventual falls. Assessment: 10 meter self-paced walked in 2 conditions - simple task (without any other task) and DT (while performing serial 3 subtractions).	Walking while Listening to Music	Gait Speed Cadence Stride Time	Significant ↑ in the MG ($p = 0.002$); Non-significant trend task x time interaction favoring the DT condition in the MG ($p = 0.081$); No changes or interaction in the CG. Significant ↑ in the MG ($p = 0.007$); Non-significant trend task x time interaction favoring the DT condition in the MG ($p = 0.056$); No changes or interaction in the CG. Significant ↑ in the MG ($p = 0.019$); Non-significant trend task x time interaction favoring the DT condition in the MG ($p = 0.062$); No changes or interaction in the CG.

Fok et al.[31]	n = 12 TG = 6 66.8 ± 9.0 CG = 6 57.7 ± 12.3	TG = 2.5-3.5 4.2 ± 2.4 CG = 1.5-3.5 5.5 ± 3.8	ON	TG: DT walking training using gait prioritization, 30' single session. Participants walked using big steps while performing a series of -3 subtractions. Subjects instructed to totally focus on big steps. CG: 30 minute sitting down reading magazine Assessment: Simple tasks (walking and subtractions alone) and DT (walking plus subtractions). Two trials in each condition at baseline, immediately after training and 30 minutes after (retention).	DT walking training (subtraction cognitive task)	Stride Length Gait Speed	Significant time x group x task interaction after training ($p = 0.03$); TG ↑ in comparison to CG; Non-significant trend task x time interaction favoring the DT condition ($p = 0.08$). Significant time x group x task interaction after training ($p = 0.03$); TG ↑ in comparison to CG; Significant task x time interaction favoring the DT condition ($p = 0.001$).
Fok et al.[32]	n = 12 TG = 6 73 ± 12 CG = 6 66.3 ± 11.7	TG = 2.5 - 3 3.9 ± 2.4 CG = 2 - 3.5 3.5 ± 2.6	ON	TG: DT walking training using divided attention, 30' single session. Participants walked using big steps while performing a series of -3 subtractions. Subjects instructed to divide their attention on both tasks. CG: 30 minute sitting down reading magazine. Assessment: Simple tasks (walking and subtractions alone) and DT (walking plus subtractions). Two trials in each condition at baseline, immediately after training and 30 minutes after (retention).	DT walking training (subtraction cognitive task)	Stride Length Gait Speed	Significant time x group interaction ($p = 0.001$); TG ↑ in comparison to CG; No significant time x group x task interaction. Significant time x group interaction ($p = 0.001$); TG ↑ in comparison to CG; No significant time x group x task interaction.

Rochester et al.[30]	n = 153 eERC = 7667.5 lERC = 77 69	eERC = 2.5 - 3 7 years lERC = 2.5 - 3 8 years	ON	Cross-Design ERC intervention Study ERC: External rhythmical cueing training, 30' sessions, 3 times per week, during 3 weeks. Auditory, visual and somatosensory cues were used: -eERC started the intervention immediately (week 1); -lERC started the intervention at week 4. Assessment: DT, walking with a tray with 2 glasses of water; Simple Task, walking without tray. Assessment at baseline, after both training periods and 6 week follow-up.	External Rhythmical Cueing Training	Gait Speed Step length Cadence	↑ On Simple Task with visual (*p* = 0.03), auditory (*p* = 0.02) and somatosensory (*p* = 0.0004) cues. ↑ On DT with visual ↑ On DT with visual (p = 0.002), auditory (*p* = 0.03) and somatosensory (*p* = 0.0004) cues and non-cue (*p* = 0.04)., auditory (*p* = 0.03) and somatosensory (*p* = 0.0004) cues and non-cue (*p* = 0.04). ↑ On Simple Task with visual (*p* = 0.001), auditory (*p* = 0.005) and somatosensory (*p* = 0.002) cues and non-cue (*p* = 0.023). ↑ On DT with visual (*p* = 0.001), auditory (*p* = 0.01) and somatosensory (*p* = 0.0004) cues and non-cue (*p* = 0.004). ↑ On Simple Task without cue (*p* = 0.03). On DT with visual (*p* = 0.002), auditory (*p* = 0.03) and somatosensory (*p* = 0.0004) cues and non-cue (*p* = 0.04).

H&Y: Horn & Yahn Scale; DT: Dual-Task; TDG: Tango Dancing Group; CG: Control Group; MG: Music Group; TG: Training Group; eERC: Early External Rhythmical Cueing; lERC: Late External Rhythmical Cueing; TUG: Timed Up & Go; DT-TUG: Dual-Task Timed Up & Go; FoGQ: Freezing on Gait Questionnaire; 6MWT: Six Minutes Walking Test.

26) were evaluated at 3, 6 and 12 months, with no significant between group differences at baseline in age, gender, physical activity levels, disease duration and severity.[25] There was a significant group by time interaction in forward and DT walking speed, the tango group exhibiting a higher velocity at 6 and 12 months. There was also a significant interaction in FoGQ and 6MWT performance: the control group displayed a deteriorated level of performance at 12 months, whereas the tango group showed no decline.

After the second year of intervention (24 months),[26] the ten remaining participants (Tango = 5; Control = 5) underwent the same evaluation protocol, because no significant between-group differences were detected.[26] There was a significant group by time interaction on DT-TUG time, as the tango group improved performance over time while the control group worsened. There was also a significant interaction on the 6MWT performance: the control group declined at 24 months, but the tango group group showed no changes over this same timespan. Moreover, there were no significant main effects or interactions for forward and backward walking speed, TUG time or FoGQ.

Dual Task: Music

Bruin et al.[29] compared a music group with a control group to understand the effects of DT intervention with music on gait performance of PD patients (n = 22; Music = 11; Control = 11). At baseline, there were no significant differences regarding age, gender, illness duration, disease severity, global cognitive performance and levels of physical activity. Music group participants walked during 30 minutes, 3 times a week, at a comfortable pace, while listening to music (each participant chose his/her songs) and retained their normal daily activities. Control group participants continued with their daily routines, but were instructed to avoid DT while walking regarding their usual daily contexts (e.g. talking to companions or taking pets as they walked). Each patient completed annotations regarding the daily life activities (physical activities, duration, and possible falls) performed during the intervention period. Assessed while ON medication, the participants completed the 10 meter walk, at a self-selected pace, in two different conditions: without any cognitive task and while performing a concurrent cognitive task (simple task/DT). The cognitive task consisted of a series of subtractions in sets of 3, beginning from a randomized three-digit number. For each DT trial, a new number was provided and participants were instructed to equally prioritize both the walking and the cognitive task.

After 13 weeks, there were no significant effects or time by task interactions on the outcome measures of the control group, while the music group showed a significant increase in gait speed, cadence and a reduction in stride time. Although improvements within the music group were reported in both simple task and DT, time by task interactions approaching significance were observed for gait speed, cadence and stride time. Improvements were higher in the DT condition in comparison to the simple task, suggesting differential intervention effects on gait performance. Furthermore, there were no significant main effects or interactions in the music group regarding stride length.

Dual Task: External Markers

We included three studies reporting findings on trials using DT and external markers interventions.[30-32] Rochester et al.[30] assessed the effects of 3 weeks of cue gait training on cued gait performance during both single-and dual-task gait. A total of 153 patients with PD in the ON medication period were divided into two groups, using a crossed-design trial: an "early" group received three weeks of training immediately and was subsequently transferred to the control group; a "late" group began as control and three weeks later was transferred to the intervention. There were no significant between group differences at baseline in age, gender, levodopa dosage, global cognitive functioning, disease duration and severity. The protocol lasted a total of 12 weeks as the patients also completed a 6 week follow-up assessment.

Cue gait training was delivered using a belt with a device that provided sensory cueing to address temporal gait control. Participants completed nine sessions lasting 30 minutes where they were instructed to step in time to the rhythmical cues, while performing single-, dual- or multi-task walking. In the first week, participants tried all cue modalities (auditory, visual and somatosensory) and then selected their preferred modality to use until the end of the training. However, in order to assess generalization effects, gait performance assessment was completed while patients were exposed to all three external rhythmical cues and also without any cueing for both single- and dual-task walking.

Pooled data analysis revealed improvements in gait speed for all three cueing modalities for both simple- and dual-task walking, although non-cue improvements were only observed in the dual-task condition. Regarding step length, significant improvements were reported in all three cueing modalities and non-cue trials for both single- and dual-task walking. Improvements in cadence were also observed in all three cueing modalities and non-cue trials for dual-task walking, although single-task performance was only improved without cueing.

Fok et al.[31,32] carried out two studies with similar methodologies. The first study[31] examined the effects of a single DT training session using a gait prioritization strategy on the walking performance of PD patients. Participants in the training group (n = 6) walked 30 minutes while performing three serial subtractions but they had to focus their attention on taking big steps. Participants in the control group (n = 6) completed a 30 minute walking period while reading a magazine. There were no significant between group differences at baseline in age, gender, height, levodopa dosage, global cognitive functioning, disease duration and severity.

Participants were assessed using both single and DT. Single task conditions involved either walking or performing the cognitive task, while DT required walking and performing the cognitive task simultaneously. The cognitive task included a series of three subtractions counting aloud and participants were given a three-digit number from a list of 40 random numbers between 150 and 450. Standardized verbal instructions were given to the participants before the assessment, both for simple tasks (only walking or only subtractions) and for the DTs (walking plus subtractions).

There was a significant time by group by task interaction for stride length and gait speed as the training group walked with longer strides and faster speed in comparison to controls immediately after training and 30 minutes after (delayed retention). It is also important to highlight that within the training group, both immediate and retention improvements in stride length and gait speed were clearly higher in the DT condition in comparison to simple task performance. There was a significant increase in stride length and gait speed as soon as the intervention group participants followed the instructions to prioritize attention to large steps.

The second study[32] evaluated the effects of a single DT training session using a divided attention strategy between gait and an added cognitive task. Participants in the training group walked 30 minutes and were instructed to focus simultaneously on their steps and on the cognitive task (serial three subtractions). This report included the same sample and assessment procedures as the previous study (single-task and DT walking). Regarding gait performance, there was a significant time by group interaction on stride length and gait speed as participants walked with longer strides and faster speed after divided attention training in comparison to the control group. Interestingly, there were no significant time by group by task interactions on any outcome measure, suggesting no differential effects of training on DT walking performance. The authors also reported immediate effects of training as the participants improved stride length and gait speed as soon as they initiated DT training with the divided attention strategy.

DISCUSSION

The purpose of this review was to understand the effects of DT interventions on gait performance of PD patients. Across all the included studies, there was some sort of gait performance improvement either on simple task or DT conditions. Most studies actually reported enhanced gait performance in both simple task and DT condition, although there were two studies who found that improvements were larger in DT conditions in comparison to simple tasks, which can suggest that these interventions may specifically target DT gait performance.[29,31]

Motor learning interventions for PD patients should be provided within a learning environment that emulates real functional situations as most activities in our everyday lives require DT or multi-tasking.[33] Thereby, it is important to explore the specific training effects of these interventions on DT gait performance. For instance, Duncan & Earhart [28,29] found no training effects in DT-TUG after 3, 6 and 12 months, but the intervention group displayed improvements after 24 months, while the controls had worse results. Interventions using multiple tasks such as dancing may help patients to withstand disease related DT gait performance decline over time, while still being able to achieve immediate effects on simple walking tasks.

It also important to explore if some learning strategies may be more accurate to target DT gait performance. Fok applied two single session DT training protocols which only diverged regarding the strategy used during training: gait priorization vs. divided attention strategy.[31,32] Interestingly, when using the gait priorization strategy, participants displayed larger improvements on stride length and gait speed in the DT condition when compared to simple task. Conversely, the divided attention strategy did not result in any differential effects between simple task and DT gait performance, suggesting that directing attentional resources to the walking motion can improve gait performance while not hindering the cognitive task.

External stimuli during training also seems to play a very important role in DT gait performance improvements. Tango dancing demands high level multi-tasking and progressive motor ability, as learning takes place in the presence of external cues provided by the music and the partner.[34,35] Music also seems to achieve DT specific effects as Bruin et al.[29] found higher increases of gait performance in the DT condition compared to the simple task after a walking plus listening to music intervention. Practicing two tasks at the same time allows for improved task coordinating abilities.[29,36] So if listening to music is a cognitively demanding task as the authors suggests, it is conceivable that this intervention may inadvertently provide DT training.[29,37] Finally, Rochester et al.[30] reported a wide range of improvements on DT gait speed, length and cadence when participants completed an external rhythmical cueing training using several sensory modalities, including visual stimuli.

Taking all the previous findings together, it seems that a critical component to specific DT gait performance improvements is the use of external stimuli during the intervention, which can be provided by standardized external cue devices, the pace of a song or even the somatosensory cues provided by a dancing partner. The mechanisms by which external stimuli improve gait quality in PD patients have not been well understood. It is known that dopamine depletion in the striatum of PD patients plays a role in the internal transmission mechanisms that control automatic gait,[38] predisposing patients to be more susceptible to external stimuli that act as extrinsic transmission mechanisms operating at a cortical level. Similarly, the role of the basal ganglia on motor control is clearly recognized (spatiotemporal movement and selection adjustments in motor programming) as well as the slow and inconsistent movements that come from its impairment.[39] It has been postulated that sensory guiding stimuli are bypassed by the premotor cortex and supplementary motor area before they reach the basal ganglia, compensating the impairment that PD patients experience in this brain region.[40] Furthermore, external stimuli, such as the display of lines on the ground, could have an effect on the patients' attentional mechanisms and on the execution of movements that require more planning.[41]

It is also important to highlight that some of the included studies reported significant findings on motor outcomes other than gait performance. Three studies found significant improvements in motor symptom severity in the training group in comparison to the control group,[25,26,29] while other three also reported significant changes in balance.[25,25,31] Thereby, it is important to explore whether gait performance enhancements are generalizable to more complex motor outcomes such as balance or if dual-task training also encompasses non-specific training effects which can even improve symptom severity in PD.

There are several limitations regarding the previously mentioned findings. Studies used very different intervention and assessment procedures not allowing us to clearly compare results and discuss pooled effects of DT training. Moreover, several studies do not report levodopa dosage or assess patients while ON medication. Studies also mostly included patients with mild to moderate disease severity. It has been suggested that PD patients tested during the OFF period or with several motor impairment require more attention to walking[42] and could respond differently to DT training procedures. It should also be noted that all the studies included patients diagnosed for several years, so it would be interesting to explore if early intervention DT training could reduce gait performance decline as the disease progresses. Finally, only two studies report any data regarding anthropometric measures[31,32] and it would be interesting to explore if height or weight play a role in training effect.

CONCLUSION

According to the studies analyzed in this review, applying DT protocols and different intervention types (dance, sound stimuli, visual and somatosensory) resulted in improvements in several gait related outcomes such as speed, stride time, cadence and step length. There are also some findings suggesting that DT training provides specific effects on DT gait performance, although gait without any cognitive task is also improved. The use of external stimuli during intervention seems to decrease the interference of additional tasks on gait pattern improvements. Further clinical trials should explore the role of medication dosage, disease duration and severity, on the treatment effects of DT training. Researchers also ought to explore which DT intervention components are more effective and appropriate not only to improve gait performance but also to enhance more complex abilities such as balance and daily living activities performance.

AUTHOR PARTICIPATION

Authors LAAS, TB, SM participated in the definition of the study design and the protocol. Authors EL, LAAS, SM managed the literature searches. Authors LAAS, EL, CC, TB wrote the first draft of the manuscript. All authors contributed to and have approved the final manuscript.

CONFLICT OF INTEREST

Authors declare no conflict of interest relating to this project.

EFEITO DA DUPLA TAREFA NA MARCHA EM PACIENTES COM DOENÇA DE PARKINSON: UMA REVISÃO SISTEMÁTICA

OBJETIVO: A Doença de Parkinson é caracterizada por sintomas motores e não motores que prejudicam a marcha, especialmente durante a realização de tarefas duplas/simultâneas. Estes déficits afetam o funcionamento diário do paciente já que a realização de tarefas duplas é uma habilidade crucial para a vida normal.O objetivo deste estudo foi realizar uma Revisão Sistemática sobre os efeitos das tarefas duplas sobre a marcha em pacientes com Doença de Parkinson.

MÉTODOS: Os estudos foram recuperados do MEDLINE/PubMed, SciELO e Lilacs. Adotamos a estratégia PICOS para determinar os critérios de elegibilidade. A estratégia de busca foi realizada utilizando uma pesquisa avançada MEDLINE/PubMed, SciELO e Lilacs com os seguintes termos adotados "Doença de Parkinson", "Dupla Tarefa", "Tarefas Concorrentes", "Marcha" e "Caminhada". Operadores booleanos AND e OR foram utilizados para combinação dos termos. A seleção dos estudos foi realizada por dois pesquisadores independentes que, em caso de desacordo, procuraram um consenso sobre a seleção.

RESULTADOS: Foram identificados um total de 188 artigos:169 artigos do PubMed/Medline, 10 artigos no SciELO, 8 artigos no LILACS e 1 artigo em buscas manuais. Após uma seleção inicial, 56 artigos foram analisados pelos critérios de elegibilidade e os critérios de exclusão, sendo que um total de sete estudos foi incluído na revisão sistemática.

CONCLUSÃO: De acordo com os estudos analisados nesta revisão, os diferentes tipos de intervenção incluídos (dança, estímulos sonoros, visuais e somato-sensoriais) permitem melhorias em vários indicadores de marcha tais como a velocidade, tempo da passada, cadência e comprimento do passo. A utilização de estímulos externos aparentam desempenhar um papel crítico nos efeitos espeíficos do treinamento na marcha em condições de dupla-tarefa.

PALAVRAS-CHAVE: Doença de Parkinson, dupla tarefa, marcha

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