



Review

Dual-task training to improve cognitive impairment and walking function in Parkinson's disease patients: A brief review

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ABSTRACT

In daily functional activities, the body needs the ability to perform two or more tasks at the same time (such as talking while walking). However, the gait disorder of patients with Parkinson's disease is aggravated when performing dual tasks, which seriously affects their quality of life. Therefore, the medical management plan should offer effective exercise training programming to improve Parkinson's disease patients' ability to perform dual tasks. Most traditional exercise intervention methods only focus on the perspective of exercise or cognition, ignoring their interaction, and fail to adequately resolve the dual task obstacles associated with Parkinson's disease. Some scholars put forward the concept of dual-task training and have applied dual-task training to patients with neurological disorders and have achieved good therapeutic effects. Therefore, this article summarizes the research literature concerning dual-task training to improve cognitive impairment and walking function of Parkinson's disease patients, to evaluate and discuss possible mechanisms of action, and provide a basis for adjuvant treatment and rehabilitation of Parkinson's disease patients.

Introduction

Parkinson's disease (PD), also known as paralysis agitans, is becoming a common chronic neurodegenerative disease,¹ especially in the elderly. Clinical motor PD symptoms include resting tremor, muscle rigidity, abnormal posture, and gait. In addition to motor symptoms, cognitive dysfunction is one of the most common non-motor comorbidities in PD patients.^{2–5} The prevalence of mild cognitive impairment in early PD patients is as high as 34%⁶ of the population. PD is associated with dysfunction in daily life that seriously affecting the quality of life and increased mortality.^{7,8} As the population ages, the number of PD patients increases.⁹ The World Health Organization predicts that by 2030, China's PD patients will number approximately 5 million individuals. At present, the cause of PD is not clear but is likely related to heredity, age, and the environment. Clinical treatment includes surgery, drug control, and rehabilitation.¹⁰ Long-term drug use has large side effects, and surgical treatment is effective, but the cost is high. Exercise as an ancillary method has few side effects, easy to do, economically beneficial, proven to positively affect gait, posture control, and balance ability of PD patients.^{10–12}

The human body's control of gait and posture depends on the motor system's ability to properly regulate the participation of sensory and

cognitive functions and is the common interaction link between the sensory system and the central nervous system.¹³ The simplest activity is talking, walking, picking up a cup to drink, and writing. Participating in any one of these activities while listening to music requires the ability to perform two or more activities at the same time. Thus, the ability to perform two or more activities at the same time in daily functional activities is very important.¹⁴ Non-PD people or PD patients' daily activities include cognitive participation. When PD patients perform motor and cognitive tasks at the same time, motor tasks that rely on visual guidance are not significantly impaired, but cognitive tasks that do not rely on visual guidance are significantly impaired. PD researchers have proposed that improvement of motor and cognitive functions in PD patients is achieved by modification of different motor and cognitive pathways.¹⁵ While traditional exercise interventions often focus only on the ability to perform skill-based sports, the relationship between sports skills and cognition has been ignored. This lack of investigations regarding the interaction between these variables has failed to adequately resolve to overcome obstacles for properly completing dual-task in PD patients. Scholars have put forward the concept of dual tasks and applied dual-task training (DT) methods for improving the health of patients with neurological diseases such as brain injury and Alzheimer's disease to achieve improved therapeutic effects,¹⁶ and to successfully perform two tasks at the same time.¹⁷ Most daily functional activities process external

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List of abbreviations

PD	Parkinson's Disease
DT	Dual-task training
HY	HoeHN and Yahr modified scale
CDTT	Cognitive dual task gait training
MDTT	Motor dual task gait training
CGT	Consecutive task training
IDT	Integrated dual-task training
mHYS	HoeHN and Yahr Stage
UPDRS III	Unified Parkinson's Disease Rating Scale part III
TUG	Timed Up and Go

information while performing motor tasks, but distractions such as making mobile telephone calls while walking distract from performing these daily functional activities.¹⁸ DT generally involves a primary exercise or balance task such as walking, standing on the front or rear of one's feet, and a distracting secondary task. The secondary task is composed of different forms of cognitive activities such as a simple motor task like holding a water cup or turning one's head. Other secondary tasks are a memory task such as memorizing numbers, or a calculation task such as addition or subtraction.^{19,20} DT refers to the simultaneous training of individuals to do two tasks; the main motor task and the secondary distracting task.¹³ Recently, some new literature reviews on the effects of DT on PD have been published. For example, Li, ZL, De Freitas, TB and others have explored the effects of DT on PD patients and proposed that the use of DT during training can improve the gait performance, motor symptoms, and balance ability of patients.^{21,22} However, there are still few scholars studying the effect of DT on the cognitive dysfunction of PD patients, and the control of gait and posture in PD patients depends on the ability to regulate sensory and cognitive functions of the motor system. At the same time, many review studies only explore the impact of DT on the walking or balance ability of PD patients, but they lack the exploration of its internal mechanism. This study aims to discuss the theoretical basis and methods of DT, the effect of DT application in PD patients, and the efficacy mechanism of how DT affects PD patients in depth. Therefore, this article summarizes the research literature concerning the use of DT to improve cognitive impairment and walking function of PD patients, evaluate and present possible mechanisms of action, and provide a basis for adjuvant treatment and rehabilitation of PD patients.

Research methods

Literature search

A literature search from the Web of Science, PubMed, Medline, CNKI, Elsevier, Wanfang databases, and other websites was completed, and data were collected and analyzed. The keywords were Parkinson's Disease AND dual-task training AND cognitive impairment AND walking function, Parkinson's Disease AND dual-task therapy AND cognitive dysfunction AND walking ability, Parkinson's Disease AND dual-task intervention AND cognitive impairment AND walking ability. Two independent researchers conducted the search. If there was disagreement between them, a third examiner was recruited. After sorting and evaluating the retrieved studies, the literature was summarized regarding the effects of DT on cognitive impairment and walking function of PD patients. In order to better understand the relationship between exercise and PD, a follow-up literature search was completed within CNKI, CSSCI, WOS databases using the key-words Parkinson's disease, exercise training, and walking ability as the subject terms. Citespace was used to perform statistical analysis to construct a visual map (Fig. 1).



Fig. 1. Constructing a knowledge map of related information regarding Sports-Parkinson's disease. Through visual analysis and literature review, it is found that physical exercise or physical exercise can promote the recovery of motor dysfunction in Parkinson's disease patients to a certain extent. In the past few years of research, there have been a lot of evidences that exercise has a protective effect on the brain. The study of Parkinson's disease animal model found that exercise promotes the remodeling process of brain function, and finally changes the behavior.

Included studies

Controlled and randomized controlled trials, uncontrolled clinical trials, and pilots of randomized controlled clinical trials in the effect of dual-task training on cognitive impairment and walking function in individuals with PD were included in the review. A total of 842 studies were found. After applying the eligibility criteria, seven studies were selected (two clinical trials, one randomized controlled trials, and four pilot studies).

Research results and analysis

The theoretical basis and methods of DT

The literature supports that DT improves the automatic procedures of actions. The demand for attention is reduced while automation is enhanced. Consequently, DT improves the ability to perform secondary tasks at the same time.²³ DT improves the coordination between two or even multiple tasks, and the end result is that individual task performance is improved.²⁴ In addition, the needs of each task are specific, and thus, DT should be completed in various different environments to improve the performance of dual tasks in a variety of settings.

Primary DT exercises include aerobic exercises such as walking, cycling, and jogging; resistance exercises; and chair-up training; and balance training such as standing on the front or ball of the foot and standing on the rear or heel of the foot feet side by side.²⁵ Secondary attention-requiring or cognitive tasks include math calculation tasks such as continuous subtraction by three and/or continuous subtraction by seven²⁶; memory tasks such as letter and picture repetition and number recall; auditory tasks, and other such tasks. Christian et al.¹⁸ conducted a 6-week intervention on cognitive and gait task training in PD patients. Training included 30-min of walking and cognitive tasks (working memory tasks, reaction time tasks, language fluency tasks, discriminative decision-making tasks, and 10 min of functional exercises). The results of this study support that DT effectively improved patients' gait parameters.²⁷ Yang et al. conducted a 3-week intervention performed 3 times a week for 30 min each session of DT in PD patients using activities such as repeating words while walking, increase or decrease numbers by three,

answer simple questions "yes" or "no", reciting shopping lists, speaking, singing, and reciting essays as secondary tasks. Their data support that the exercise-cognition dual-task training improves the walking ability of PD patients.²⁰

Application effect of DT in PD patients

In completing functional walking, patients must maintain a certain degree of posture control to properly walk. PD patients must also properly mobilize cognition processing to best use external information to effective complete dual-tasks such as walking and talking.²⁸ Some scholars have proposed that an interaction between cognitive ability and walking ability exists. Cognitive training has been found to improve athletic performance, and gait training improves cognitive ability. These improvements are reflected in the rationality of limited attention resources.^{29,30} DT applied to the elderly was shown to prevent falls and is now used as a therapy for reducing falls risk.³¹

DT utilizing cognition and gait training was evaluated to determine the impact on motor function of nerve injury patients.^{32,33} Fritz et al.³⁴ found that adding cognitive tasks to gait or balance training improved gait, balance, and cognitive abilities in neurological disorders patients. Hsiu-Chen et al. proposed that DT could interfere with motor function and cognitive performance, and this interference was likely caused by the types of motor tasks completed.³⁵ Therefore, dual tasks such as cognition-walking and cognition-bicycle were evaluated for motor and cognition function. Hsiu-Chen et al.³⁵ found similarities and differences in the impact of these two forms of DT exist. As a result, cognition-bicycle DT was proposed as a potential adjuvant treatment strategy to promote PD patients motor and cognitive functions. Conradsson et al.³⁶ evaluated PD patients who completed a 4-week intervention of performed 3 times a week for 30 min each session. Their data support that 12 cognitive-motor dual tasks (CDTT) in reducing the double support time during CDTT walking, and exercise-motor dual-task training (MDTT) reduced the gait changes during MDTT walking.³⁶ DT can effectively improve the gait performance of PD patients under dual-task conditions.³⁷ In particular, DT improved gait speed and step length.³⁷ Different DT strategies have different training effects on PD patients. DT is also used in the rehabilitation of PD patients to improve functional walking.³⁸ Mirelman et al.³⁹ conducted a 6-week treadmill intervention with virtual reality performed 3 times a week for elderly, mild cognitive impairment patients, and PD patients. Interventions combined with virtual reality augmented treadmill training and reduced fall risk, improve mobility, and enhance cognitive function.³⁹

Data provided by Fernandes et al.⁴⁰ supports the use of DT to improve executive function in PD patients. De Freitas et al.²² completed a systematic review and pointed out that gait and balance training are more beneficial than single-task training or no intervention for patients with mild to moderate PD.²² However, Fernandes et al.⁴⁰ found that participants completing DT performed significantly better in the closed-eye lateral swing test in the single task training group.⁴⁰ DT was evaluated for various aspects of gait (speed, step length and rhythm) and balance (middle-lateral and anteroposterior balance in the closed-eye test). Rennie et al.⁴¹ evaluated the immediate and long-term effects of highly challenging balance and gait training on the pace, rhythm, variability, asymmetry, and posture control of PD patients. Highly challenging balance and gait training improved pace, rhythm, and variability in the gait of PD patients in the short term but not in the long-term.⁴¹ Li et al.²¹ argued that dual-task training was more effective in improving gait performance, motor symptoms and balance in patients with Parkinson's disease relative to other forms of training or non-intervention.

The curative effect mechanism of DT

Although many studies have shown that DT is effective in the improvement of the cognitive impairment and walking function of PD patients, the neurophysiological mechanism of this effect is currently not

known.⁴² Wu et al. found that when performing DT compared with performing a single task training, PD patients are activated on both sides of the anterior cuneiform lobes.⁴³ PD patients are believed to need more brain processing resources to compensate for basal ganglia dysfunction when performing DT. The difficulty in performing DT in PD patients is likely due to limited attention, central executive function defects, and low automation of tasks. Thus, DT can reduce dual-task interference and provide improved treatment of PD patients.⁴⁴ Rosenfeldt et al.⁴⁵ found three sub-regions that play a major role in the execution of DT.⁴⁵ The frontal cortex of the prefrontal cortex is mainly involved in coordinating and processing secondary tasks, and the medial prefrontal cortex is mainly based on motivational cues. The reward expectation of the task, and the lateral prefrontal cortex are mainly responsible for the selection of rules and the task of characterization.⁴⁶

At present, most scholars agree the possible DT rehabilitation mechanisms affecting PD patients include the plasticity theory of the brain and the theory of motor relearning. That is, PD patients can promote brain remodeling through a large number of repetitive and targeted exercises completed to improve the automation level of actions.⁴³ More attention should be allocated to secondary tasks to improve the PD patient's functional ability.¹⁴ Petzinger et al.⁴⁷ support- combining goal-based training to improve the cognitive and motor control components of mild to moderate PD patients through experience-dependent neuroplasticity. Basic research on PD animal models has also begun to show that exercise improves neuroplasticity at the level of synaptic connections and neural circuits.⁴⁷ Some scientists believe that DT can optimize the allocation of cognitive training, increase the coordination of primary and secondary tasks, and improve the ability of PD patients to perform dual tasks.⁴⁸ Binda et al.⁴⁹ animal reported that exercise is an external stimulus relative to the body, which can induce limited endogenous nerve repair mechanisms, increase axons and dendritic branches, speed up information processing, and improve performance.⁴⁹ Shin et al.⁵⁰ reported that DT activates the basal nucleus on the right side of the brain,⁵⁰ and the difficulty of secondary tasks is related to the activation of the basal nucleus region, which can optimize the ability to allocate attention and improve the ability to perform dual tasks.⁵¹

Conclusion

In summary, the damage to the central nervous system of PD patients makes completing complex activities of daily living most difficult. This article summarizes the existing literature regarding the use of DT in the treatment of PD patients. Generally, DT is effective for improving cognitive impairment and walking function of PD patients, but the specific neurophysiological mechanism for the beneficial effect remains to be determined. Whether increased DT in PD patients improves the quality of life of patients after discharge needs further verified. In the future, the efficacy of DT should be actively evaluated to provide a basis for the ancillary treatment and rehabilitation of PD patients, so as to allow patients to return to society as soon as possible and regain a higher-quality life.

Submission statement

This manuscript is an original work that has not been previously published, nor will it be under consideration for publication by any other journal before a decision has been made by Sports Medicine and Health Science. If accepted, this manuscript will not be published elsewhere.

Authors' contributions

Yanpei Zheng: Writing – review & editing. **Zhaoli Meng:** Writing – review & editing. **Xiao Zhi:** Writing – review & editing. **Zhanghua Liang:** Writing – review & editing. All authors read and approved the final manuscript.

Conflict of interest

The authors declare no financial or other conflicts of interest that could influence the interpretations of this work.

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