Chapter

Dementia and Physical Therapy

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Abstract

Cognitive functions allow us to perform complex tasks on a day-to-day basis. When we move or want to perform a functional task, not only the integrity of the motor systems is needed, but also those cognitive functions that help plan and execute movement in challenging environments. Currently, the physical therapy of people with Parkinson's disease, little by little, integrates the cognitive abilities of patients to the motor rehabilitation of the disease. Most studies to date have proven the effectiveness of this dual-task integration in mild or moderate stages of the disease. However, in more serious stages, we do not fully know the effectiveness of physical rehabilitation in patients who already have dementia or cognitive impairment. This chapter aims to review the latest findings in this regard, to know what are the implications of dementia in Parkinson's disease on the motor performance, and to unravel the new lines of study that researchers and clinicians should follow in the area of physical rehabilitation in advanced stages of Parkinson's disease.

Keywords: cognitive impairment, functional movement, physical therapy, Parkinson's dementia, executive functions

1. Introduction

The cognitive abilities of people who start a physical rehabilitation program are essential to ensure the effectiveness of therapeutic exercise. The ability to understand and follow instructions, the ability to perform exercise with the indicated frequency, as well as the ability to integrate physical improvements into activities of daily living are factors that influence the success of physical treatment in the short and long term. In people with Parkinson's disease (PD), the effects of physical rehabilitation are widely documented in the scientific literature, establishing the possibility of motor learning in people with PD during early stages of the disease. However, patients could experience cognitive impairment over the evolution of PD whose clinical expression, severity, and progression can be variable. These cognitive changes can range from subtle impairment to mild cognitive impairment (PD-MCI) or to more severe deficits such as dementia due to Parkinson's disease (PDD), and they can appear from early to more advanced stages of the disease [1]. In people with PD-MCI or PDD, the implementation of a rehabilitation program acquires additional challenges that can hinder its effectiveness. This may be one of the reasons why in the scientific literature on the effects of physical treatments, we constantly see that having a normal cognitive state is included as a criterion for participation of people with PD, frequently evaluated by a quick cognitive screening with the mini-mental Parkinson's examination [2] or the Montreal Cognitive Assessment [3].

Comparing with age-matched healthy groups, people with PD exhibit a faster decline in certain cognitive domains like executive, attentional, visuospatial, and memory functions [4]. Even though these cognitive alterations of people with PD are greater than typical for normal aging, they are measurable through standardized cognitive scales, and they are consistent with PD-MCI, they do not critically interfere with daily functioning. Conversely, PDD involve more severe cognitive deficits, and these have a significant impact on day-to-day and functional activities [1, 5]. In addition, PDD is often accompanied by behavioral features such as apathy, mood disorders, excessive daytime sleepiness, and psychosis [6]. Despite these differences, it should be noted that PD-MCI increases the risk of conversion to dementia 6-fold [1].

2. How does cognitive impairment influence functional movement?

A person's functional capability is the result of the interaction of three factors: the individual, the objective task, and the environment where the task takes place [7]. This means that the movements respond to a specific demand that involve what we going to do and where we going to do it. From the individual, not only is the indemnity of the motor system necessary to exercise functional movement, but an interaction with the sensory and cognitive systems is also required. We can say with total certainty that movement is a cognitive-sensory-motor phenomenon. More specifically, when we exercise a voluntary movement, the cognitive system acquires special relevance in the motor control.

Action planning and selection, action initiation, online adaptation during actual execution, and inhibition of an ongoing action are among the main cognitive tasks directly involved in the execution of the voluntary movement, although not the only ones involved [8]. These components related to the action control belong to higher cognitive processes to modulate and produce behavior: the executive functions. Associated with the prefrontal cortex, the impairment in one or more of the components of executive functions has been related to motor abilities such as walking efficiently and safely. Seen from an example, poor self-awareness of limitations, an aspect of volition, might result in an increased risk of falling, or the impaired planning skills could result in getting lost or choices that produce inefficient pathways or unnecessary effort to arrive at a destination [9]. Other executive functions related to functional movement under multiple stimuli are dual execution and multitasking, considered as the ability to organize and perform tasks optimally simultaneously, intercalating them. This ability to perform more than one task at the same time is the basis of the functional environment, where people are exposed to several cognitive demands.

On the other hand, attention has been also determined as essential in goal-directed movement. Attention can be classified into separate functions, including focused or selective, sustained, divided, and alternating. This cognitive function is defined as the state of observation and alert that allows awareness of what happens in the environment. It is a capacity or process by which specific mental resources are generated and directed on the most relevant aspects of the environment or the most appropriate actions, maintaining the appropriate state of activation to achieve a goal or purpose. To carry out this process, it is necessary to focus on specific stimuli, ignoring other minor ones. The attention is necessary to initiate and adapt a movement that is developed voluntarily. For example, when we want to start walking in unfamiliar terrain or modify the gait pattern to change direction or avoid an obstacle, the first thing we do is direct our attention to this requirement, controlling the gait from the motor cortex.

In addition to attention and executive functions, other authors have mentioned that cognitive processes such as emotion (motivation) or memory are also crucial to develop motor tasks with a certain objective within a certain environment [7]. Anyway, either by the connections of the basal ganglia with the primary motor cortex, supplementary motor area, premotor cortex, and cingulate motor area (motor circuit) or, on the other hand, with the dorsolateral prefrontal cortex and lateral orbitofrontal cortex (executive circuit), movement in Parkinson's disease is threatened from mild to moderate stages long before dementia appears.

3. Can physical therapy improve the cognitive performance?

In the previous section we have seen the relationship that cognitive functions have to generate voluntary movement. But what happens the other way around? Can motor practice influence cognitive performance? The truth is that non-pharmacological interventions are an essential part of the treatment in PD. Physiotherapy, speech therapy, psychology, and occupational therapy are the most common nondrug health strategies to alleviation the symptoms directly related with a poor development a functional live. Even when pharmacological and surgical treatment improved immediate parkinsonian symptoms and, in consequence, quality of life, there has been a limited effect on axial symptoms, i.e. gait, posture, balance, speech, and swallowing [10] and also on cognitive deficiencies [11]. These disabilities not only have a powerful impact on the activities of daily living for people with PD but are also strongly related to dependency and mortality [12].

In this regard, physical rehabilitation, physiotherapy, or physical therapy has shown an effect beyond the physical characteristics itself that it pretends to rehabilitate, and in addition, it will also depend on the type of physical therapy that is implemented. This has been demonstrated in aging people without associated pathologies, as well as in people with PD. In healthy aged people it has been shown that resistance exercises and resistance training are powerful physical intervention strategies to induce meaningful functional brain changes, especially in the frontal lobe, which are accompanied by improvements in executive functions [13]. In the same way, aerobic and coordination exercises seem to be more beneficial to cognitive processes than other exercises such as stretching or balancing to improve cognitive functions like memory, processing and perceptual speed, and attention [14]. On other hand, in recent years, the effectiveness of multi-domain physical therapy in different population has gained much prominence. This kind of therapy involves both motor and cognitive practice, and it has been studied through dual-task or multi-task training, where the persons performs a primary task, such as gait, while performing other secondary cognitive (or motor) task. In this type of exercise, the patients have to shift attention from one task to another in order to achieve the objective of both, e.g. walking and saying aloud a shopping list [15]. In this way, the dual-task in physical rehabilitation imitates a habitual functional context within the therapy itself, where people practice a motor exercise subjected to the usual demands of the environments in activities of daily living. That is why studies generally report greater cognitive improvements with multi-domain training in older age [16]. Specifically, clinical trials using dual motor-cognitive tasks led to improvements of domains related to global cognitive functions and inhibitory control in older people [17].

In people with PD this also has been widely studied. Besides the poor pharmacological effect on cognition, the importance of finding noninvasive therapies that improve cognitive deficiencies is crucial for two main reasons. The first is that cognitive impairment in people with PD can appear in the early stages of the disease, and on the other hand, mild cognitive impairment represents a significant risk factor for early dementia [10]. Recently published systematic reviews have been summarized that physical therapy has a positive effect on global cognitive function, processing speed, sustained attention, mental flexibility, visuospatial, and executive functions in people with Parkinson's disease [10, 18–21], besides motor function. However, the main function benefiting from the different physical training is the executive and global cognitive function measured through different cognitive screening (**Figure 1**). This may be due to the described relationship of the executive functions in the planning and initiation of the voluntary movement. Although it has been described that several physical therapy programs can have an impact on cognitive performance, it is worth asking what type of strategy achieves the best effects. Aerobic [22–25], multimodal [26–28], and multi-domain [29] are the most referenced techniques in the literature that measures the effects of cognitive functions through a standardized test for it. While multi-domain refers to interventions targeting two or more domains, as physical exercise and cognitive training, in this section we use multi-modal as different components of the same domain, e.g., the combination of strength and balance training in the same program. However, in some publications, both terms may refer to intervention programs with components from different domains.

Studies with multi-domain intervention have shown that the ability to transfer the performance improvements depended largely on the demands, particularly cognitive, of the specific task involved [30]. One of the most repeated examples in the literature is the use of virtual-reality-based training; however, this requires that patients have individual sessions and the availability of the respective equipment. A more feasible multi-domain training option is dual-task training, which can be applied individually or in groups. The studies so far that analyze the effectiveness of dual-cognitive task training assess the performance of the secondary cognitive task itself, but not the cognitive function through a standardized test. Even so, studies have been published indicating that dual motor and cognitive tasks improve executive functions measured through the Trail Making Test [15].

Finally, the revised systems reviews indicate that trials that used longer interventions were associated with improved attention and processing speeds, whereas

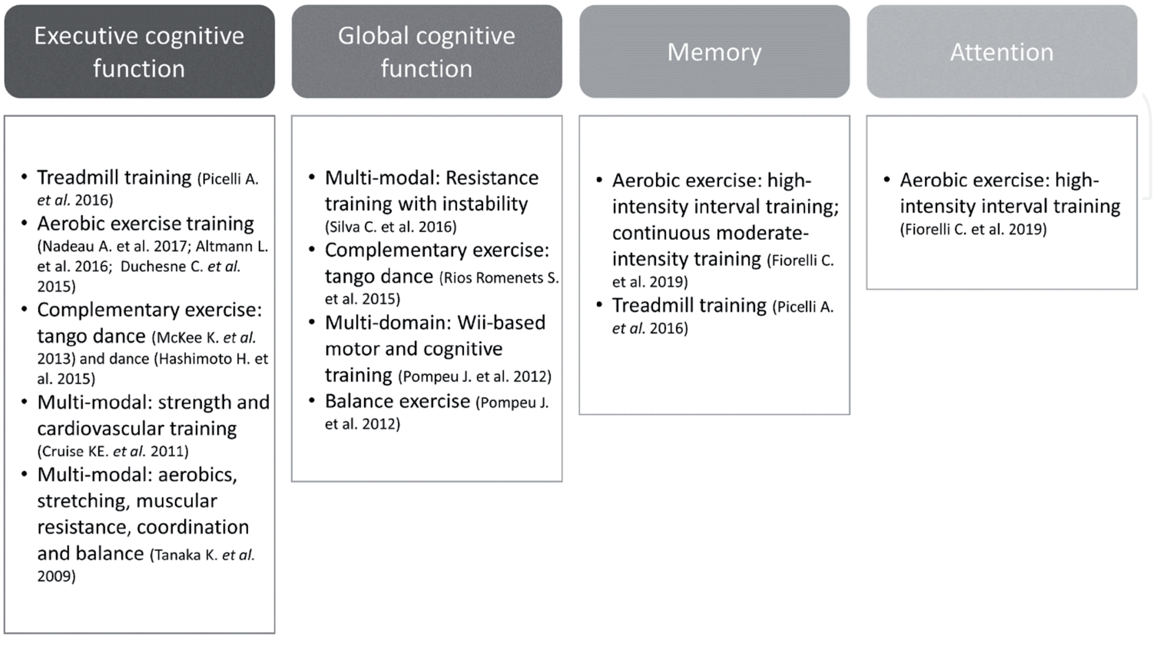

Figure 1.
Physical training applied to people with Parkinson's disease has shown a significantly positive effect on one or more cognitive functions, measured through standardized tests for cognitive performance.

trials conducted among individuals with mild cognitive impairment tended to show more memory improvement compared to non-dementia samples [19, 21].

4. Physical performance in people with and without dementia

We have reviewed that physical rehabilitation can have effects on cognitive functions even when these are not the objective of the intervention. But what happens to the physical performance when people with PD have dementia, have mild cognitive impairment, or do not have any cognitive disability? Regardless of the range of signs and motor dysfunctions that we can find in PD, we will analyze this issue from the functionality of the hand and gait.

4.1 Hand functionality

Impairment in voluntary hand movements results from deficits characteristics of PD such as slowness of movements and difficulty in executing sequential movements. Also, the performance of hand fine motor skills is not the same for people with PD without cognitive impairment and people with PD as well as cognitive impairment and dementia. Although the scientific evidence of these differences in samples exclusively with PD is limited, a few authors specifically indicate in which domains of hand functionality we can observe these differences (**Table 1**). Dahdal et al. determined that people with PD and mild cognitive impairment exhibited a significant worse motor performance in precision (to guide a stylus through a narrow curved track without touching the sides), dexterity (to insert 25 long and short pins into holes in a platform), and velocity of arm-hand movement (time spent to precisely hit 20 subsequent points lined in a row) tasks [31]. Likewise, Tan et al. found that people with PD and dementia have poorer hand function in pen-holding, buttoning, and knotting actions than do the patients without dementia [32].

Authors	Task/test	PD MCI	PD non-MCI
Dahdal et al. [31]	*Precision*: number of errors made by touching the sides while patients guide a stylus through a narrow curved track	−0.36 (1.04)	0.25 (0.74)
	Dexterity: duration needed to complete the task of inserting 25 long and short pins into holes in a platform	−0.28 (0.8)	0.14 (0.7)
	Velocity of arm-hand: velocity required to precisely hit 20 subsequent points lined in a row	−0.28 (0.9)	0.16 (0.6)
		PDD	**Non-PDD**
Tan et al. [32]	Pen-holding	1.2 (1.5)	0.8 (1.3)
	Buttoning	2.0 (1.6)	1.7 (1.5)
	Knotting	2.0 (1.6)	1.6 (1.5)

Means and standard deviations of the hand function outcomes. MCI, mild cognitive impairment; PDD, Parkinson's disease dementia. Differences founded by Dahdal et al. show p values <0.05. Differences founded by Tan et al. show p values <0.001. Tan et al. assessed the domains 8.1 (pen holding), 8.2 (buttoning), and 8.3 (knotting) of the Functioning Disability Evaluation Scale Adult Version with a 4-point scale that designate if there was total independence or a need for assistance when accomplishing tasks (0 = total independence, 1 = need for supervision or mild assistance, 2 = need for moderate assistance, 3 = need for maximal assistance, 4 = need for total assistance).

Table 1.
Significant differences found between people with PD, with and without cognitive impairment/dementia in hand functionality performance.

In addition to these differences, the authors demonstrated the significant correlation of precision task with age of participants and the MiniMental State Examination results [31]. Also, pen-holding and knotting performance was significantly associated with dementia in patients with moderate-to-advanced PD, which allowed the researchers to establish there is a 13% higher probability of dementia for PD patients if they had any level of disability in pen holding [32].

4.2 Gait

Gait performance has been become in an indicator of health in many pathologies. In fact, gait speed in older adults has been accepted as a reliable and sensitive measure for assessment of physiologic performance and prediction of clinical outcomes, and indeed has been regarded as the "sixth vital sign" [33]. Added to this, people with PD report that gait impairments are the most disabling motor symptoms of the disease [34]. Most of the studies when analyzing the effects of gait rehabilitation programs exclude patients with dementia or cognitive disorders in their samples, even though this group of patients suffers a worse deterioration of the walking pattern than do people with PD without cognitive disorders (**Table 2**). PD patients with cognitive impairment walked slower and had shorter step length and stride length than those without cognitive impairment [35, 36]. In those studies that only analyzed a sample of patients with dementia or cognitive impairment without a control group [37, 38], the values recorded are below normal gait pattern.

As with the parameters of hand functionality, correlations between gait variables and other parameters related to dementia have also been demonstrated in gait. Mini Mental State Examination is significantly associated with step length [35] and stride length [35]. Also, cognitive domains such as attention and visuospatial have been positively correlated with step and stride length [35].

In addition to the classic correlations between gait performance and cognitive performance, studies that search to predict cognitive decline in PD people demonstrate that gait variability is associated with lower cognitive performance [39, 40]. The variability is usually calculated through the coefficient of variation (CV = [standard deviation/mean] × 100) and indicates how stable or repeatable the analyzed

	Authors	PD MCI/PDD	PD non-MCI/PDD
Velocity (m/s)	Kim et al. [35]	0.55 ± 0.29	0.66 ± 0.30
	Chen et al. [36]	1.07 ± 1.51*	1.21 ± 1.69
	Chen et al. [37]	0.88	—
	Mc Ardle et al. [38]	0.89 ± 0.25	—
Step length (m)	Kim et al. [35]	0.30 ± 0.16*	0.38 ± 0.14
	Mc Ardle et al. [38]	0.51 ± 0.12	—
Stride length (m)	Kim et al. [35]	0.62 ± 0.30*	0.74 ± 0.28
	Chen et al. [36]	0.62 ± 0.21*	0.64 ± 0.16
	Chen et al. [37]	0.66	
Cadence (steps/min)	Chen et al. [36]	98.13 ± 16.81*	97.61 ± 11.11

Means and standard deviations of the gait outcomes. MCI, mild cognitive impairment; PDD, Parkinson's disease dementia. *Comparison with PD non-MCI/PDD is statistically significant. Authors who assess participants with mild cognitive impairment: Kim et al.; Chen, Cheng et al.; Chen, Lien et al. Authors who assess participants with dementia: Mc Ardle et al.*

Table 2.
Gait performance in people with PD and mild cognitive impairment or Parkinson's dementia.

sample is when walking. It answers the question whether the participants with PD always walked in all repetitions at the same speed or with the same stride length. These studies indicate that gait variability is an indicator or biomarker of specific cognitive domains (fluctuating attention and visual memory) in early PD, and even that it is a stronger predictor than baseline cognition [39].

5. Future of research in physical rehabilitation focused on people with PD and dementia

While dementia caused by traumatic brain injury is usually static, dementia caused by neurodegenerative diseases is usually progressive and can eventually be fatal [41]. Although motor rehabilitation impact on people with PD is widely referenced in the scientific literature, the physical effects that can be achieved with physiotherapy in people with PD and dementia are hardly documented. That is why the steps of the new research that seek to clarify the relationship between motor performance and the cognitive impairment and dementia in PD should be as follows:

Randomized control trials about the effectiveness of physical rehabilitation should be include as secondary outcomes the assessment of cognitive functions which performed may be impaired in PD: executive function, attention, speech and language, visuospatial, memory and psychological and behavioral functioning [1].

Although usually in randomized controlled trials on physical rehabilitation, the sample is subdivided by the severity of the disease, according to either the Hoehn and Yahr scale or the Unified Parkinson's Disease Rating Scale, researchers must take into account the analysis of the scope of the effectiveness of physical rehabilitation in patients with different degrees of cognitive impairment or dementia, which implies not excluding their participation in research.

Likewise, studies that introduce cognitive training in people with PD should study the effects of the intervention on motor functions such as gait, balance, and hand functionality.

Scientific publications suggest that physical interventions that include multidomain interventions have better results than physical programs that focus on a single physical aspect.

Moreover, cognitive disorder and dementia are not the only mental disorders that PD patients suffer during the course of the disease. While cognitive decline is one of the most frequent and important nonmotor symptoms in PD [4], mental disorders such as depression, anxiety, insomnia, apathy, and psychosis are other aspects that people with PD deal throughout the disease [42]. Although the alteration of executive functions is part of mild cognitive impairment, dysexecutive syndrome is a clinical picture that requires a specialized study in people with PD. Dysexecutive behavioral disorders may include distractibility, perseverative behavior, poor flexibility, and impulse control, strongly affecting the social functioning of patients. However, these symptoms are not included in the regular executive functions assessment, which is frequently focused on the initiation, inhibition, flexibility, generation, deduction, planning, and coordination of a motor task with some cognitive requirement. Roussel et al. evaluated both cognitive and behavioral domains of the dysexecutive syndrome. These authors determined that dysexecutive syndrome was observed in 80.6% (sample size = 88) of PD patients, and selectively affected either the behavioral domain or the cognitive domain in more than half of the patients [43]. Although there are still aspects to study about the scope of physical therapy for people with dementia in PD, researchers should not ignore the mental disturbances that can appear in the course of the disease.

6. Conclusions

It has been identified that people with PD and cognitive impairment have lower physical functional performance than do people with PD without cognitive impairment. This may be due to alterations in specific cognitive functions that are involved in the planning and execution of voluntary movements, such as executive functions and attention.

Studies that analyze the effects of physical rehabilitation with aerobic exercises, multi-modal or in a multi-domain context, observe cognitive improvements in their participants in addition to physical improvements. Future research should study the effects of physical rehabilitation on the different characteristics of the disease and on people with cognitive impairment and dementia since it constitutes a powerful non-pharmacological treatment tool with benefits in multiple systems.

Conflict of interest

The author declares no conflict of interest.

Abbreviations

PD	Parkinson's disease
PD-MCI	Mild cognitive impairment in Parkinson's disease
PDD	Dementia due to Parkinson's disease (PDD)
CV	Coefficient of variation

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