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EC NEUROLOGY
Research Article

Motor Imagery Effect on Gait in Parkinson's Disease: A Systematic Review

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Received: March 10, 2018; **Published:** April 10, 2018

Abstract

Introduction: Motor imagery (MI) represents the cognitive aspect of a motor act and may be defined as the ability to construct a mental action without actually executing it. It may be built mentally through two strategies (visual and kinesthetic). Parkinson's disease (PD) has an unknown etiology and is probably related to multiple causes. PD has been described as a neurodegenerative disease in which neuronal rarefaction and inclusion of Lewy bodies may occur in the small part of the nigra substance and consequent deficit in dopaminergic transmission. Despite all efforts to understand PD and the identification of several non-motor signs and symptoms, such as cognitive changes, the disease diagnosis still depends on motor manifestations such as bradykinesia, stiffness, and tremor at rest. In this context, with the PD evolution, gait disturbances are verified. MI has been used as a gait management strategy in PD since the technique seems to modulate its characteristics immediately.

Objective: Investigate, through a review, the MI effects on gait in PD.

Methods: To analyze indexed articles in the databases: PubMed/Medline; PEDro and Google Scholar. The studies found were classified according to the PEDro level of evidence and Oxford Center for Evidence-Based Medicine.

Results: In total, nine relevant studies on this topic were found. Three of the studies suggest that kinesthetic MI is useful in the PD treatment with and without freezing of gait (FOG) when compared to visual MI. One study evidenced discrepancies between motion and MI, indicating that this may contribute to FOG. Another suggests that Levodopa increases activity in the motor regions (midbrain and supplemental motor area), putamen, thalamus and cerebellum, as well as reduces the activity of the premotor, parietal and brainstem regions of patients with advanced PD. A sixth study showed a decrease in the globus pallidus activity and increased activity in the supplemental motor area during the MI of gait in PD. The seventh study showed no benefit in gait improvement when MI associated with physiotherapy or relaxation. Two studies pointed to the efficacy of the questionnaires applied in PD: (1) it addresses the FOG as a gold standard to diagnose PD (NFOG-Q) and (2) analyzed the vividness of the imagined movement by comparing two questionnaires (KVIQ and GIQ).

Final Considerations: It seems that kinesthetic MI has a relevant effect in the PD treatment when compared to visual MI, especially in gait characteristics. However, the results still have to be interpreted with caution.

Keywords: *Motor Imagery; Gait; Walk and Parkinson's Disease*

Introduction

Motor imagery (MI) is a cognitive ability linked to the voluntary motor act representation [1,2] and may be defined as the ability to imagine a task without actually executing it [3-5]. MI may be accomplished through two strategies: (1) kinesthetic, where the individual feels mentally performing the task in first-person perspective and (2) visual, where the individual mentally observes the movement being presented in a third-person perspective [5,6]. The imagination and the proprioceptive perception of the same task are related motor skills and may be controlled voluntarily [7]. The observed similarities between execution movement (EM) and MI may occur in two motor act aspects, which are temporal and biomechanical [8-13]. For instance, the time taken to walk a fixed distance (5, 10, and 15 meters) is similar to the time spent imagining walking the same length [8]. Another example would be the similar biomechanical relation of the number of executed and imagined movements of the same task in a fixed time [14-17]. In this context, both temporal and biomechanical relations involve the principle of isochrony [11].

First described by James Parkinson in 1817 [18], Parkinson's disease (PD) presents a variable prevalence in the active population and higher than 1% in the people over 60 years of age, with no difference between genders [19]. This disease etiology remains unknown, is probably related to multiple causes (genetic, environmental factors, etc.) [20] and its neurodegenerative characteristics present as a rarefaction in the dopaminergic neurons, as well as the presence of intraneural eosinophil, infiltrates in the small part of the nigra substance of the midbrain [21]. Cholinergic changes [22], dopaminergic alterations, among others, lead to neurophysiological modulations in parietal-frontal areas [23-25] and direct pathways (movement facilitation, D1 receptor) and indirect (inhibition of movement, D2 receptor) paths of inhibitory circuits in the base nuclei, especially in the caudate nucleus [26]. These modulations result in motor changes such as stiffness, bradykinesia, resting tremor, postural instability (trunk anteropulsion), gait with short steps and decreased speed with increased cadence (festination) [21]. Another frequent motor manifestation is freezing of gait (FOG), which presents the prevalence of 60% in the PD population and may be defined as an episodic inability to generate an active step [27], lasting less than 30 seconds [28].

MI has been widely used in a variety of clinical conditions, such as amputation disorders [29,30]; lumbar [31] or cervical spine dysfunctions [32] and neurological diseases [33-35], including PD [36-40]. In general, MI is a cognitive task integrated to the motor system (preparation areas and movement programming) that directly interferes with the ability to perform functional tasks [1,2], including the gait characteristics of PD patients [36-37,39,41,42]. In this context, with the PD evolution, gait disturbances are verified. MI has been used as a gait management strategy in PD since the technique seems to modulate its characteristics immediately, relieving their symptoms and improving their quality of life (gait). Therefore, the present study has a goal to investigate, through a review, the MI effects on gait in PD. We hypothesize that MI strategies (visual and kinesthetic) present different and relevant impact on walking in PD.

Materials and Methods

This study is a systematic review, and it has a goal to synthesize and critically evaluate the evidence pertinent to the theme.

Data source

For the proposed theme development, two books were used, one on "Principles of Neural Science" [26] and the other on "The Neurophysiological Foundations of Mental and Motor Imagery" [5]. Articles from a broader period (1955 - 2017) were used, with the most significant volume of information published in the last ten years, to provide a theoretical substrate for the contextualization and discussion of the theme. 32 articles were published in the last ten years (2008 - 2018), and the other references (20 studies) were released over ten years (≤ 2007).

Search in databases and inclusion criteria

This systematic review used only articles indexed in the following databases: PubMed/Medline; PEDro and Google Scholar, using the following keywords: motor imagery; gait; walking and Parkinson's disease without a predetermined period. The studies found were classified according to the Pedro level of evidence (available at http://www.pedro.org.au/) and Oxford Center for Evidence-Based Medicine (available at http://www.cebm.net/ocebm-levels-of-evidence/).

Exclusion Criteria

We specially selected studies that used MI on the gait of PD patients. The 757 excluded articles from the search involved other contexts, using: (1) video therapy to approach gait in PD (Google scholar); (2) visual imagery (visualization of images) for relaxation and non-motor imagery in PD (PEDro); (3) gait analyzes in PD and/or FOG, but not involving MI, as well as works that spoke only on gait in PD or MI separately, but not including both (Pubmed/Medline and Google scholar)and (4) precisely, in the Google scholar database, only one study was used [42], since most articles had been found in the other databases or addressed other clinical conditions other than PD.

Results and Discussion

In total, 9 studies involving MI and gait in PD from 2007 to 2015 were selected. Table 1 summarizes the database search results, the PEDro and Oxford evidence levels, as well as the impact factor of the journals in 2017. Table 2 summarizes the work involving the MI effects on gait in PD patients. Most of the studies analyzed (7 articles) used a good design criterion (1B - controlled and randomized clinical trial).

Data base	Articles found	Selected articles	Author and Year	Level of Evidence PEDro	Level of Evidence Oxford	Impact Factor of the journal in 2017 (JCR)
PEDro	4	3	Tamir., *et al*. (2007)	6/10	1B	4.107
			Braun., *et al*. (2011)	8/10	1B	4.083
			El-Wishy., *et al*. (2013)	7/10	1B	0.06
Pubmed/Medline	12	5	Snijders., *et al*. (2011)		1B	3.985
			Cohen., *et al*. (2011)		1B	3.197
			Pickett., *et al*. (2012)		1B	1.722
			Maillet., *et al*. (2015)		2C	4.530
			Peterson., *et al*. (2015)		1B	3.866
Google Scholar	750	1	Snijders., *et al*. (2012)		1C	4.484

Table 1: *Databases searches' results.*

Legend: *1B: Randomized Controlled Trial; 1C: Therapeutic Results, including Sensitivity and Specificity; 2C: Observation of Therapeutic Results/Ecological Study and JCR: Journal Report Citation.*

Author and year	Sample	Intervention	Methodology	Results and Conclusions
Tamir., *et al*. (2007)	n = 23 PD idiopathic.	Three exercise protocols were applied for 1h, twice a week, during 12 weeks: (1) calisthenics; (2) functional tasks and (3) relaxation.	**Experimental group:** Combination of physiotherapy and MI (n: 12). **Control group:** Only physiotherapy in motor tasks (n: 11).	Only in the experimental group, there was a significant improvement in the motor tests performance (UPDRS) and cognitive (Stroop and clock). The authors concluded that the combination of MI and physical practice might reduce bradykinesia in PD.
Cohen., *et al*. (2011)	n = 11 with FOG n = 13 without FOG n = Ten healthy subjects (control). All of them of similar ages.	Participants should perform and imagine (kinesthetic strategy) that they were going through a door (to induce FOG).	It was built a system of doors and a corridor with different port openings (80, 90, 100, 110, 120 and 130 cm) and distances (1.5, 3 and 6m). The time spent for each task was timed.	In the kinesthetic MI task, all were slower at the narrow door, and FOG subjects were slower at the wider door. FOG subjects show a high temporal discrepancy in ME and MI, unlike PD subjects without FOG and controls. The authors concluded that: (1) FOG is not associated with internal representations; (2) discrepancies between ME and MI may contribute to FOG, and (3) the interpretation of brain MI imaging of gait in FOG subjects should be cautious.
Snijders., *et al*. (2011)	n = 25 Levodopa® patients. n = 13 with FOG n = 12 without FOG n = 21 healthy subjects (control).	The participants were instructed to visualize images of a corridor with a list and a disk and oriented to make the MI of the gait and IV of the disk in the fMRI.	During the fMRI, the time required to perform and imagine walking at different distances was quantified (2, 4, 6, 8 and 10m).	The time between ME and MI of the tasks did not present statistical difference. FOG patients showed higher activity in the midbrain locomotor areas, indicating specific alterations in this region, which may be related to FOG in PD.
Braun., *et al*. (2011)	n = 47 in total n = 22 control group n = 25 experimental group.	During six weeks, both groups underwent physiotherapy and MI (experimental group) or relaxation (control group) for 1h, twice a week.	Visual analogue scale (VAS); TUG test and a 10m walk test.	No significant effect was observed between the groups, and the authors concluded that no differences were observed between combinations of physiotherapy with MI and relaxation.
Pickett., *et al*. (2012)	n: 28 PD patients (11 women, mean age 71 years) n: 33 healthy individuals (16 women, mean age of 69 years, control).	Participants were divided into two groups, and the KVIQ (Vividness in MI) and GIQ questionnaires were applied (walking back and forth as well as spinning in a 1-meter circle to the right and left).	Application of two questionnaires (KVIQ and GIQ) and evaluated the FOG while the patient performed MI, as well as the relation of FOG to the vividness of the imagined movement (KVIQ).	The ME and gait MI did not show any difference between the control and PD groups (with and without FOG), as well as between the GIQ and KVIQ scores, indicating that motor impairment does not prevent gait MI. The authors concluded that GIQ might be administered in healthy and PD subjects to evaluate gait MI.
Snijders., *et al*. (2012)	n: 50 PD patients n: 32 with FOG n: 18 without FOG	Tasks: (a) leave a chair, walk 2.5m and make a 180º turn; (b) walk 15m at three different speeds and (c) rotate in one direction (360º) and the opposite direction (540º).	FOG questionnaire (NFOG-Q) and the subjective question: "Do you sometimes feel as if your feet are being glued to the floor?"	The clinical evaluation identified FOG in 24 of 32 patients. Also, one of the 18 patients without FOG presented criteria for diagnosis. NFOG-Q was defined as a gold standard (sensitive and specific) to identify FOG in PD patients.
El-Wishy., *et al*. (2013)	n: 11 (Idiopathic PD women) n: 15 (Idiopathic PD men)	G1 (control): physiotherapy program and educational video. G2 (experimental): physiotherapy program, the video showing normal gait and the subject performing MI. They were performed four weeks in a row, three times per week, for 25 to 30 minutes. The exercises were: (1) calisthenics; (2) specific functions and (3) relaxation.	The kinematic parameters of gait were analyzed by kinemetry (step length, gait velocity, and ankle, knee and hip excursions).	In the pre-test, the groups showed no difference (baseline). In the post-test, G2 presented a significant difference in all gait parameters analyzed, compared to G1. The authors concluded that the MI program (video therapy and MI) improves gait in PD.
Peterson., *et al*. (2014)	n: 39 in total n: 19 with PD n: 20 controls	The patients' gait was executed and imagined during five tasks: (1) to move forward (simple task); (2) walk backward; (3) return to the left and (4) right, bypassing a circle (complex tasks) and (5) stand still.	The five tasks were imagined in the fMRI, measuring the activity of the five locomotor regions: (1) supplemental motor area; (2) globus pallidus; (3) putamen; (4) midbrain and (5) cerebellum. All participants presented a visual sensation of MI (visual and kinesthetic) in KVIQ > 3 (moderate intensity).	When compared to controls, PD participants showed a reduction in activity on the globus pallidus and increased activity in the supplemental motor area (comparing tasks 1 and 2). The authors concluded that the supplemental motor area in PD might present compensatory adaptive activity during gait strategy.
Maillet., *et al*. (2015)	All participants with advanced PD. n: 4 men n: 4 women	Participants were evaluated in two moments with a 12h interval: (1) without and (2) with Levodopa® (control task). Participants performed three tasks: (1) walking at two distances (6 and 10m); (2) kinesthetic MI of gait and (3) visual MI of gait.	Positron emission tomography (PET) and KVIQ before and after MI tasks.	KVIQ vividness levels in kinesthetic strategy improved significantly after training, with no difference in visual strategy. In PET, the kinesthetic MI of gait presented different results. With Levodopa® (control task), the following areas were accessed: motor and frontal associative; thalamus; basal ganglia and cerebellum. Without Levodopa®, the pre-motor, parietal and mesencephalic areas were accessed. The authors concluded that the medication increased activity in the motor, putamen, thalamus and cerebellum regions, as well as reduced the activity of the pre-motor parietal region and the brainstem. The results suggest a cerebellar contribution in gait pathophysiology in PD.

Table 2: *Studies involving the MI effect on gait of PD patients are summarized in chronological order.*

Legend: *PD: Parkinson's Disease; FOG: Freezing of Gait; ME: Movement Execution; MI: Motor Imagery; VI: Visual Imagery; UPDRS: Unified Parkinson's Disease Rating Scale; m: Meters; fMRI: Functional Magnetic Resonance Imaging; TUG: Timed up and Go; KVIQ: Kinesthetic and Visual Imagery Questionnaire; CIQ: Gait Imagery Questionnaire; h: Hours; cm: Centimeters and NFOG-Q: New Freezing of Gait Questionnaire.*

Motor imagery effects in different clinical contexts

Several works in neurosciences have evidenced the MI benefits and propose its use in improving performance and/or functional recovery in different contexts: sports practices [43]; in geriatric patients [44]; amputation disorders [29,30]; lumbar [31] or cervical spine dysfunctions [32]; gait disorders [45]; changes in postural balance [14-16,46] in both unipodal [44,47,48] and bipodal support [49,50], as well as in neurological diseases [33-35], including PD [36-40]. The gait and balance dysfunction are often associated with the PD progression [51], and these changes in motor control are not fully understood [1,52]. Thus, the MI use in gait management in PD has sought to reorganize the motor function of this population (see table 2).

Motor imagery effect on the motor control of human gait in general

When analyzing healthy individuals who were to perform ME and gait MI at different distances (2, 4, 6, 8 and 10m), a temporal similarity (mental chronometry) was observed according to the increase in distances [53], showing that neurophysiological processes (primary motor cortex) increase brain activity in the areas of lower limb internal representation (gait) and postural control [45]. These internal gait representations are not affected when compared to elderly individuals with and without PD, although there is a relevant difference between the participants with and without FOG [36]. MI in PD individuals (with and without FOG) during functional magnetic resonance imaging (fMRI) showed that FOG patients had a decrease in parietal-frontal activity and increased activity in the midbrain locus (related to FOG), compared to patients without FOG [37,54]. Also, it has been suggested a decrease in the globus pallidus activity and a higher compensatory activity during the MI walking in PD, specifically in the supplemental motor area [55]. These changes may result in changes characteristic of FOG and postural control observed in PD patients [37]. Thus, the New Freezing of Gait Questionnaire (NFOG-Q) has been suggested as a gold standard (high sensitivity and specificity) for the FOG diagnosis in PD [42].

Motor imagery effect on the freezing of gait in Parkinson's Disease

FOG represents an episodic inability to generate a useful step in the absence of any cause other than secondary parkinsonism [27] and is a relevant factor for the risk of falls [51]. The prevalence of this motor phenomenon is 20% to 60% in the PD population [27]. Usually, the FOG is presented as hesitation of the steps or "getting stuck," for instance, when passing through a door changing the environment, enter a place with many people, among other conditions [36]. Therefore, this disorder directly affects the quality of life of PD patients [56].

Evidence suggests that PD patients with FOG may present structural and functional alterations in the mesencephalic locomotor region [54], the globus pallidus and the supplemental motor area [55], indicating that specific alterations in these regions may be related to FOG in PD during MI task [37,57]. The brain reorganization exerted by the MI in PD can control sensory and motor feedback during functional tasks [38]. However, it seems that this effect may be related to the MI strategy type (visual or kinesthetic). Specifically, kinesthetic MI has shown a more significant impact on brain activity when compared to the visual MI strategy [57]. Besides, it has been demonstrated that kinesthetic MI has a relevant effect on FOG in PD [36].

The combination between physical practice and MI has presented contradictory results. Although MI combined with physical therapy exercises for six weeks has not shown any significant effect [40], the combination of MI and physical practice may reduce cognitive and motor symptoms in PD, especially bradykinesia [39]. Similar results have been observed using video therapy and MI, noting improvement in the gait of these patients [41].

Traditionally, the work points out similarities between ME and MI of the same task (principle of isochrone) [11], presenting temporal and biomechanical relation in healthy individuals [8-17]. Corroborating these results, similarities were also observed between ME and MI of the gait of PD patients with and without FOG [37,52]. However, when investigating FOG specifically, the participants were slower in the task with the wider port, and no similarities were found between ME and MI in this group. However, this similarity between ME and MI was maintained in the non-FOG and control groups [36]. In this context, studies suggest that MI in PD may be used to improve gait in both patients with and without FOG, but their results to date should be interpreted with caution.

Final Considerations

The present study suggests that kinesthetic MI has a more significant effect on the PD patients' treatment when compared to visual MI, mainly in gait functional recovery. Probably, the higher impact on the kinesthetic IM strategy was perhaps observed because this modality accesses proprioceptive representations linked to kinesthetic memory, which may result in an improvement in the individual's locomotor ability. However, one limitation of the studies found was the lack of two MI strategies use (visual and kinesthetic) in the control and PD groups (with and without FOG) to determine their relevance. Although the work involving the topic is still few (nine in total) and the level of evidence (PEDro > 6 and Oxford 1B for most studies), indicate that the results are reliable. However, further studies are needed to deepen knowledge about the subject.

Author Contributions

Nélio Silva de Souza, Marco Antônio A. Leite, Ana Carolina G. Martins, Carla Ayres and Isabela da S. Carvalho participated in the acquisition of data. Nélio Silva de Souza, Marco Orsini, Marco Antônio A. Leite,Bruna Velasques, Pedro Ribeiro, Rossano Fiorelli, Silmar Teixeira, Fernando Silva-Júnior and Victor Hugo Bastos guided the design and organization of the study. All authors participated in the revision of the manuscript and gave final approval for the version submitted for publication.

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