International Journal of Neurorehabilitation
ISSN: 2376-0281

Zeilig and Shiller, Int J Neurorehabilitation Eng 2016, 3:3
DOI: 10.4172/2376-0281.1000e124

Editorial Open Access

Advanced Technology to Enhance Rehabilitation Outcomes: Parkinson's Disease

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Introduction

Parkinson's disease (PD) is a progressive movement disorder characterized by bradykinesia, resting tremor, muscular rigidity, and the loss of postural reflexes. The brains of people with PD show degeneration of dopaminergic neurons in the substantia nigra. This leads to progressive dopamine depletion in movement-control centers in the basal ganglia, including the striatum, globus pallidus and subthalamic nucleus, resulting in the motor impairments of PD [1]. Common non-motor symptoms include pain [2], fatigue, depression, constipation, sleep disorders, swallowing dysfunction, and psychosis [3].

PD is a significant public health problem, with increasing incidence with age. In western countries, the estimated prevalence is 1-2% in persons over 65 years and 3-4% in persons over 85 years [4]. In countries with demographic shifts toward increasing elderly population, the incidence will likely increase.

Diagnosis and management of PD have traditionally been provided by neurologists. Primary intervention consists of medications to improve motor function and reduce motor fluctuations, dyskinesias, and tremor. This includes levodopa/carbidopa, dopamine agonists, MAO-inhibitors, and anticholinergic medications. Low frequency repetitive transcranial magnetic stimulation (rTMS) is also used to improve motor system function [5]. In advanced disease, patients refractory to medical and noninvasive treatment may experience improved motor function from deep brain stimulation to the subthalamic nucleus or globus pallidus.

Multidisciplinary Rehabilitation is Essential for People with PD

PD is of special interest to rehabilitation professionals because patients face numerous challenges to their quality of life and functional abilities. The motor impairments give rise to a number of significant functional barriers including impaired mobility, difficulty with activities of daily living, and increased incidence of falls.

Further, people with PD frequently suffer from other diseases of aging, including cardiovascular diseases, chronic lung disease, osteoarthritis, cerebro-vascular disease, and dementia. These can lead to other medical issues such as impaired oxygen delivery, joint and muscle dysfunction, and cognitive impairments. These impairments can be synergistic with neurological impairments of PD in accelerating functional loss and deterioration of quality of life. In particular, cognitive impairment has a large influence on gait function and evidence suggests that it constitutes a significant obstacle to gait recovery [6]. PD thus results in significant personal and societal costs.

As previously discussed in this journal, the complexity and potential severity of impairments and disability in PD suggest the use of a multidisciplinary approach. However, the variability in clinical presentation, and breadth of available clinical approaches, present a challenge to the rigorous study of multidisciplinary treatment. To date, there is no evidence-based template for optimal configuration of a multidisciplinary approach [7]. However, there is substantial evidence for individual interventions, and emerging knowledge about the processes underlying recovery and restoration of function for people with PD.

Rehabilitation to Improve Mobility in PD

Growing research has demonstrated that rehabilitation interventions can slow or reverse some of the debilitating functional impairments of PD. Intensive multidisciplinary rehabilitation has been shown to improve mobility after treatment at one year follow-up [8]. A Cochrane review found that physical therapy can improve gait speed, two- or six-minute walk test, reduce freezing of gait, improve sit to stand to walk, improve balance, and clinician rated disability. In agreement with observations made above, the review found a broad variety of techniques employed by therapists, and was not able to distinguish which techniques are most effective [9].

A number of specific interventions have been shown to improve mobility in people with PD. Balance training improves postural instability [10]. Treadmill training is associated with increase gait speed and stride length [11,12]. Resistance exercise appears to increase strength and endurance [13], but not balance and gait parameters [14]. Whole body vibration therapy improves some gait parameters [15]. Evidence suggests that pool-based physical therapy results in better balance, quality of life and reduced falls compared to land-based therapy [16]. Home exercise programs have been shown to improve spinal flexibility and functional reaching ability, and high intensity exercise has been shown to be more effective than low intensity exercise [17].

In a controlled trial of minimally-supervised home exercise vs. regular care [18], exercise reduced falls in people with less severe, but not more severe PD. In all patients, the exercise group had improvements in affect, quality of life, transfer ability, and decreased fear of falling. Interestingly, the patients with more severe disease who did not enjoy reduced falls, were found to do less exercise in post-hoc analysis. Comparison of supervised vs. unsupervised exercise revealed that therapist-supervision of exercise improved activities of daily living, motor, mental, emotional functions and general health quality [19]. Tai Chi training has been shown to decrease falls, improve balance and gait compared to stretching and strengthening [20]. Further, there is evidence that exercise not only improve functional outcomes, but may be protective and decreases degeneration of dopaminergic neurons in the substantia nigra [21].

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Received May 19, 2016; **Accepted** May 20, 2016; **Published** May 27, 2016

Citation: Zeilig G, Shiller AD (2016) Advanced Technology to Enhance Rehabilitation Outcomes: Parkinson's Disease. Int J Neurorehabilitation 3: e124. doi:10.4172/2376-0281.1000e124

Multidisciplinary Rehabilitation to Improve Function and Quality of Life in PD

While the best particular configuration of multidisciplinary care has not been determined, the approach can also improve conditions that have broad impact on function and quality of life in PD. For instance, multidisciplinary rehabilitation has been shown to improve sleep in PD [22]. Cognitive training improves processing speed, visual memory, and functional disability [23]. Cognitive behavioral therapy has been effective in treating depression and impulsive behavior [24]. Finally, there is mixed evidence for the efficacy of occupational and speech therapy to improve activity of daily living [25], and communication [26].

Applications of Rehabilitation Technology in PD

One of the benefits of advanced rehabilitation technology is an ability to increase the underlying determinants of neuroplasticity. This includes motivation, repetition, intensity, and specificity of exercises [27]. Emerging research suggests that perturbation-based training can improve reaction speed and reduce falls in various populations [28]. Computer-controlled treadmills enable customized multi-directional gait perturbation combined with treadmill training [29-31]. Robotic training in rehab has been shown to improve function in persons with stroke compared to traditional therapy [32]. Research is needed to explore its use in PD. Furthermore, advanced technologies such as virtual reality offer promise in the integration of cognitive and motor aspects of rehabilitation [33]. Remote monitoring technology, including body-fixed sensor devices, can give clinicians and researchers direct information about mobility, motor fluctuations, falls risk [34], and indirect information about cognitive status and autonomic stability [35]. The use of sensors to enhance supervision of home exercise is particularly relevant in light of evidence that supervision enhances compliance, and that supervised long-term exercise can enhance functional outcomes in PD [36]. Technology-assisted balance training has been shown to prevent falls with enduring effects at one year follow-up [37].

Physiologic Mechanisms of Rehabilitation—Relevant to PD?

We are beginning to understand the mechanisms by which rehabilitation interventions enhance function in PD. There is evidence that altered synaptic plasticity is part of the pathogenesis of motor dysfunction in PD [38]. And it has been shown that exercise enhances neuroplasticity in the basal ganglia in persons with Parkinson's disease [39]. Evidence suggests that appropriately timed pharmacologic intervention can be synergistic with physical training in increasing learning and neuroplasticity in PD [40,41].

It is unknown to what degree rehabilitation interventions can enhance appropriate neuroplasticity toward improved function in people with PD. It is also unknown what drivers of neuroplasticity are most relevant to people with PD. This is an important area of investigation, as it may help direct resources toward the most effective modes of rehabilitative care.

Exciting Possibilities for Research and Clinical Care

Research is unlocking the basic processes that contribute to degeneration of dopaminergic pathways in PD. Likewise we are clarifying the physiology of interventions that can slow degenerative processes, enhance neuroplasticity and learning, and stimulate functional recovery. Meanwhile, Rehabilitation Technology has improved our ability to create a rich environment of sensorimotor challenge and stimulation, to enhance motivation, and to monitor and supervise clinical status and independent training of patients in the community. There is potential for rich synergy among these developments. Increasing clarity about physiologic mechanisms of recovery can refine our rehabilitation research. By using measures of neuroplasticity along with standard functional measures in research protocols, we can determine which aspects of multidisciplinary interventions are most relevant to the recovery process. This may allow a more precise application of rehabilitation technology and interventions to optimize physiologic changes and functional recovery.

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