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ROLE OF PHYSICAL ACTIVITY IN PARKINSON'S DISEASE PREVENTION AND MANAGEMENT – A LITERATURE REVIEW

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ABSTRACT

Introduction and purpose: Parkinson's disease (PD) is a progressive neurodegenerative disorder that is characterized by both motor and non-motor symptoms, such as bradykinesia, tremor, rigidity and instability of the posture. Millions of people suffer from the disease around the world, affecting not only the patients, but also public health systems. Pharmacological interventions exist, although aside from reducing symptoms, no drugs that stop the progression of PD have been developed. That is why interventions from outside the realm of pharmacology have garnered increased focus of the academics, one of them being physical activity. In recent years, an extensive research was done to prove or disprove a link between exercise and PD's prevention and management.

What this study aims to do, is to comprehensively gather and review current state of literature in the field of physical activity's role in prevention and management of Parkinson's disease.

Material and methods: Our method of research was to scan the databases of academic articles easily accessible on the Internet, such as PubMed, Google Scholar and others. Our team searched for "Parkinson's disease" together with various terms, such as "physical activity", "exercise", "prevention", "management", "symptoms" and "treatment". Following that, the obtained data were manually analysed.

Conclusions: This review, based on quoted research, points to physical activity as a valuable addition to the standard pharmacological treatments, with its potentially beneficial effects all across the PD's development timeline. From disease prevention and modification, to management of the symptoms, both motor and non-motor alike.

Additional research ought to be conducted in the field to explain the mechanisms and to maximize the effect of the interventions. Nevertheless, contemporary state of knowledge heavily suggests incorporating physical activity into standard treatment strategies for Parkinson's disease.

KEYWORDS

Parkinson's Disease, Physical Activity, Exercise, Parkinsonism, Prevention, Management

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Introduction and Purpose

Parkinson's disease (PD) is the world's second most common neurodegenerative pathology, ranking below solely Alzheimer's disease. With the increasing share of elderly people in humanity as a whole, Parkinson's disease is being named as one of the factors that are bound to severely impact aging populations economically[1].

Epidemiological data available from various sources states, that PD affects 1 to 2 people per 1000 in any population[2]. Unfortunately, this number cannot be applied to population of the elderly. Among people over 60 years of age the prevalence goes upwards significantly, affecting 1 person in a 100[2]. What cannot be overlooked are the differences in lifetime risks between sexes. Some estimates put the lifetime risk of a male acquiring the disease at nearly double the female risk[3].

According to a study published this year, by Su et al., which sought to create a projection of PD's prevalence for the future, due to inevitable aging of the population, the number of patients affected by the disease is expected to more than double with 112% increase between years 2021 and 2050. The number of patients affected worldwide forecasted by the scholars by the final year of the projection exceeds 25 million[4].

Given the situation, it is natural for scientists to look closer into the available means of combating the PD. With well-established standard pharmacotherapy, such as levodopa and dopamine agonists, not able to halt the progression of the disease, while at the same time not free from side-effects[5], there has been an increasing scientific effort in recent years exploring potential factors aiding PD's management but also prevention.

Naturally, trying to establish factors that reduce the risk of PD has been done in the past - some of the suggested results however, are known to have a plethora of harmful effects on the organism, notably tobacco use, alcohol consumption and nonsteroidal anti-inflammatory drugs use[6]. Knowing that, physical activity emerges as a promising protective factor[7], void of such side effects[8–10], while also having multitude of positive effects outside of central nervous system[11–13].

Physical activity has also been recently viewed in research as part of a multimodal approach to PD's management, among mental exercise and NIBS (noninvasive brain stimulation)[14].

This literature study's aim is to systematically collect, combine and examine critically all the available academical sources of knowledge concerning the correlation of physical activity and Parkinson's disease. Furthermore, it aims to establish not only what is currently known, but also what is not yet known to better project future therapies.

State of Knowledge

Pathophysiology

Parkinson's disease is described as a neurodegenerative disease of the central nervous system, that is characteristic in its pathology for its gradual degeneration of dopaminergic neurons, primarily in the substantia nigra, a midbrain structure associated with movement. This mechanism is responsible for releasing an insufficient amount of dopamine, which causes the observable motor symptoms[15].

Another notable pathology observed in patients with PD are the Lewy bodies. These are inclusion bodies, precisely pathological aggregations of protein, which are present in parts of the brain altered by the disease. Lewy bodies are present in vast majority of individuals diagnosed with Parkinson's disease[6].

Despite our ever-expanding knowledge of brain's functioning on a molecular level, there is much yet to be discovered concerning PD's pathogenesis in the organism. From the exact role of Lewy bodies[15] to the precise process responsible for destruction of dopamine-releasing cells[16].

There have been proposed solutions to the unknowns, although no single mechanism can thoroughly explain all. Most recent theories point to a wide variety of mechanisms occurring at the same time, finally resulting in cell death[17].

Symptoms

PD's symptoms can be generally divided into two main groups – motor and non-motor symptoms. The fundamental motor deficits, established in 1817 in first written account of the disease by James Parkinson are: resting tremor, stiffness, slow movement, postural and gait disturbance[18, 19]. While the disease progresses, the symptoms worsen, and their spectrum widens, causing an impactful decline in quality of life of the individual affected by the disease[6, 15].

Examples of symptoms not associated with movement most commonly experienced by patients encompass psychiatric disturbances such as elevated anxiety and depression, chronic pain and tiredness, impaired cognition, dysautonomia and wide variety of sleep disorders, including insomnia[6]. Dysautonomia can manifest in multitude of symptoms from different organ systems. In digestive system it may be responsible for wide range of disturbances, from abdominal pain to constipations[15], while in urinary system it can cause elevated frequency and urgency of urination[20].

An important, yet overlooked aspect of PD is dementia. Research shows it is rapidly progressing with age, affecting approximately every 3 out of 4 patients, that have been living with the disease for over a decade[21].

Pharmacological interventions

The most commonly used drug acting against Parkinson's disease is levodopa[15]. Being able to cross the blood-brain barrier, levodopa is there converted into dopamine[22], which lack of is responsible for motor symptoms observed in patients[23]. Despite currently being the drug of first choice in PD's treatment[24], levodopa is not free of side effects, owing to consequences of being metabolised into dopamine in other organs than the brain[25].

Another frequently used drug utilizing dopamine-related ways of targeting the disease are monoamine oxidase B (MAO-B).inhibitors[15]. Monoamine oxidase B is an enzyme that is responsible for dopamine breakdown in the brain. By inhibiting that process, these drugs preserve the dopamine available to use by the neurons[26].

There is no known cure for Parkinson's disease, pharmacological or otherwise[27]. Known drug interventions can only slow the progression of the condition or alleviate its symptoms, without stopping the disease's course[15]. New drugs targeting PD are constantly being developed[28], however considering the current state of knowledge, it is reasonable to turn to non-pharmacological interventions, such as use of physical activity as a therapy, for aid.

Role of physical activity in PD's prevention

Similarly to most pathologies, there are a few factors proposed to be protective against Parkinson's disease. Unfortunately, among those most often put forward and with most academic support are tobacco smoking[29] - known for decades to be directly linked to cancer[30] - and caffeine consumption[31], which, generally harmless, can have damaging effect on health when overused[32]. However, one of those potential factors is also physical activity. With little to no side effects while at the same time having a multitude of positive influences on the whole organism[33], it became a point of interest for researchers in recent years.

A meta-analysis study from 2018, done by a group of researchers led by Xuexian Fang, aimed to prove or disprove the speculated association of physical activity and decreased chance of Parkinson's disease in life. After compiling the data from eight prospective studies with over half a million participants across them, including 2192 Parkinson's disease patients, the researchers reached their conclusions. Firstly, according to their findings, physical exercise does lower the risk of acquiring PD later in life – however, not *all* exercise. Highest total activity as well as highest moderate to vigorous activity gained supreme results, while light activity proved non-significant in lowering the risk of PD. Secondly, the researchers found a linear correlation between the amount of physical activity in one's life and the decreasing risk of the development of Parkinson's disease. The risk lowers with increased hours of weekly physical activity. However promising these results are, the article notes, that the association is stronger in men than women, while described linear relation applies only to men. No such correlation was found while analysing women's results[34]. This observed phenomenon may be explained by pointing to a smaller sample size. Only half of the studies included in the meta-analysis included women, with just one study with the number of female participants affected by Parkinson's disease exceeding 150[35].

However, not all studies come to the same conclusion concerning differences in response to physical activity between sexes. A different article, a description of a follow-up cohort study by Portugal et al. referenced previous unsuccessful attempts of establishing a strong association of physical activity with decreased risk of PD in women, while at the same time presenting results contrasting with the status quo. Contrary to a study by Fang et al., Portugal concluded that higher levels of exercise throughout woman's life resulted in decreased incidence of Parkinson's disease, while at the same time excluding the possibility of being explained by reverse causation. Portugal's study analysed 1196 PD cases, it is therefore a larger female sample size than used in Fang's meta-analysis[36].

Role of physical activity in slowing PD's progression

The association of physical activity with good health is as old as the academia itself. Nowadays, sport has become a staple of a healthy lifestyle, which is also well-established scientifically. Positively impacting the whole organism, from obvious beneficiaries like heart[11] and lungs[12] to the lesser known as intestines[13], one can overlook its effects on the nervous system[37]. This very link was investigated in the past few years, focusing on Parkinson's disease among others. The researchers tried to prove if changes in the structure and function of the brain resulting from physical exercise can perhaps slow down Parkinson's disease progression[35].

In the previous chapter of our review, we have focused on exercise as a way of preventing the disease. The exact mechanism responsible for sports delaying the day of the diagnosis is not yet fully understood, however one might theorize that the very same effect occurs even after PD has been determined. Unless pathological processes of Parkinson's disease somehow stopped the beneficial role of exercise, the mechanism could last – to which extent is a matter of research[37].

There is evidence both from animal and human studies suggesting that aerobic training results in changes in the central nervous system, specifically the brain, both in structure and function[37]. There have been two notable recent studies involving rodents with induced parkinsonism, that were made to exercise for a period of four weeks. The first one, performed by Wang et al. in 2013, showed improvements in motor symptoms related to the disease on top of observed alterations in rats' motor cortex activation patterns, suggesting neuroplastic effect of the exercise[38]. The second one, by Al-Jarrah et al., resulted in an increased angiogenesis in the brains of parkinsonian mice[39]. Angiogenesis, the process of creating new blood vessels, increases brain's blood flow, a parameter known to be decreased in patients suffering from Parkinson's disease[40].

Animal trials can lead to optimistic conclusions concerning the link between PD and exercise, although one should proceed cautiously while attempting to forecast these results from animal to human organisms[35]. That being said, evidence from human trials is very limited. As of yet, there has been no investigation performed on a larger scale with a goal to prove aerobic exercises' effect on brain's neuroplasticity. The most comprehensive meta-analysis concerning this subject is based on only 13 studies totalling 214 participants.

Drawing from a small sample size, the results of the studies varied. Most of them concluded with a positive outcome – physical activity indeed appeared to promote neural plasticity, as demonstrated by changes in levels of neuronal adaptation markers tested – while some resulted in no such difference between test groups at all. The results, however hopeful, require a significant amount of research in the future. To establish a firm connection of exercise and slowing the progression of Parkinson's disease, there is a need for investigation with a larger sample size. Until such studies are performed, the evidence can be described as weak at best[41].

Role of physical activity in PD's symptoms management

The third and final element of the Parkinson's disease continuum and physical activity's correlation that has been investigated in recent years are the symptomatic manifestations. The characteristic symptoms of PD, depending on their type and intensity present in patient, can be life-altering. Exercise is one of the interventions researched into its potential to lessen both movement and non-movement related clinical features.

Meta-analysis performed by Radder et al. in the year 2020 aimed to establish a link between different types of physical activity and motor-related signs of Parkinson's disease. After gathering the results of 191 randomized controlled trials, in which nearly 8000 people took part, they created their own, broader analysis. Radder's team looked at 12 different types of exercise, that can be safely performed by patients affected by PD and compared them. The conclusions are overwhelmingly positive from the perspective of the patients. Only one out of twelve types of exercise proved to have no impact on motor symptoms of Parkinson's disease nor improving quality of patient's life, specifically dual task training. Patients performing any of the other eleven modalities resulted in improvements in at least one of four categories investigated. Four types of exercise yielded improvements in as much as three categories[42].

The results of this meta-analysis are encouraging, however, the focus of the academia on the subject should not end at this point. Much is yet to be discovered, from dose- and sex-specific response to understanding the effects of exercise for specific symptoms and at different stages of the disease. Tailor-made physical therapy, taking into account individual needs and preferences of the patients should be a goal for the future.

Unfortunately, the scope of clinical features of PD goes beyond what can easily be seen by people not affected by the disease. It is also characteristic for its symptoms not related to movement encompassing psychiatric conditions such as heightened anxiety and depression, but also chronic pain and fatigue and sleep disorders[14, 19]. Encouragingly, vast body of evidence from the available literature, including randomized controlled trials, speaks in favour of physical activity's positive influence across the full spectrum of non-motor symptoms in individuals with PD[43–46].

Summary

Physical activity's highly beneficial role on multiple stages of Parkinson's disease development timeline is suggested by an ever-increasing collection of evidence. Firstly, available data shows its neuroprotective role, shielding individuals from the development of PD. The strongest established link points to moderate to vigorous levels of activity, with additional research needed into male vs female responses to intervention, as the data remain inconclusive.

Secondly, some animal and growing amount of human trials point to physical activity as a mean of slowing the disease's progression potential in the mechanism of increasing the neural plasticity. Time will tell if these conclusions will stand after more populous trials investigating them are performed.

Data collected from researching meta-analyses of randomized controlled trials shows large amount of evidence strongly linking numerous types of physical activity in improving the management of all kinds of symptoms presented by PD patients. These included both motor and non-motor clinical signs as well as patients' intellectual capacity and their reported quality of life.

Physical activity, with its non-invasive nature and well-known positive influences for not only the central nervous system, but the whole human body, positions itself as a valuable additional therapy in management of PD, particularly knowing the limits of standard pharmacological treatment and its side-effects.

Potential investigations in the field performed in the nearest future ought to focus on explaining the mechanisms to maximize the effect and to better help the affected by the disease with potential individually designed interventions to best suit the patient's needs and preferences. However not fully understood and explored, physical activity presents itself as a hope for the future for millions of people worldwide already affected by Parkinson's Disease, and for an uncountable number of future patients.

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REFERENCES

1. de Lau LML, Breteler MMB. Epidemiology of Parkinson's disease. *Lancet Neurol*. 2006;5(6):525-535. doi:10.1016/S1474-4422(06)70471-9
2. Tysnes OB, Storstein A. Epidemiology of Parkinson's disease. *J Neural Transm Vienna Austria 1996*. 2017;124(8):901-905. doi:10.1007/s00702-017-1686-y
3. Elbaz A, Carcaillon L, Kab S, Moisan F. Epidemiology of Parkinson's disease. *Rev Neurol (Paris)*. 2016;172(1):14-26. doi:10.1016/j.neurol.2015.09.012
4. Su D, Cui Y, He C, et al. Projections for prevalence of Parkinson's disease and its driving factors in 195 countries and territories to 2050: modelling study of Global Burden of Disease Study 2021. *BMJ*. 2025;388:e080952. doi:10.1136/bmj-2024-080952
5. Zahoor I, Shafi A, Haq E. Pharmacological Treatment of Parkinson's Disease. In: Stoker TB, Greenland JC, eds. *Parkinson's Disease: Pathogenesis and Clinical Aspects*. Codon Publications; 2018. Accessed March 26, 2025. http://www.ncbi.nlm.nih.gov/books/NBK536726/
6. Kalia LV, Lang AE. Parkinson's disease. *The Lancet*. 2015;386(9996):896-912. doi:10.1016/S0140-6736(14)61393-3
7. Fan B, Jabeen R, Bo B, et al. What and How Can Physical Activity Prevention Function on Parkinson's Disease? *Oxid Med Cell Longev*. 2020;2020:1-12. doi:10.1155/2020/4293071
8. Hendriks HFJ. Alcohol and Human Health: What Is the Evidence? *Annu Rev Food Sci Technol*. 2020;11(1):1-21. doi:10.1146/annurev-food-032519-051827
9. Nicotine and health. *Drug Ther Bull*. 2014;52(7):78-81. doi:10.1136/dtb.2014.7.0264
10. Harirforoosh S, Asghar W, Jamali F. Adverse Effects of Nonsteroidal Antiinflammatory Drugs: An Update of Gastrointestinal, Cardiovascular and Renal Complications. *J Pharm Pharm Sci*. 2014;16(5):821. doi:10.18433/J3VW2F
11. Isath A, Koziol KJ, Martinez MW, et al. Exercise and cardiovascular health: A state-of-the-art review. *Prog Cardiovasc Dis*. 2023;79:44-52. doi:10.1016/j.pcad.2023.04.008
12. Jagroop D, Dogra S. Physical activity among Canadian adults with obstructive respiratory diseases. *Appl Physiol Nutr Metab Physiol Appl Nutr Metab*. 2018;43(10):1075-1082. doi:10.1139/apnm-2017-0865
13. Campaniello D, Corbo MR, Sinigaglia M, et al. How Diet and Physical Activity Modulate Gut Microbiota: Evidence, and Perspectives. *Nutrients*. 2022;14(12):2456. doi:10.3390/nu14122456
14. Pupíková M, Rektorová I. Non-pharmacological management of cognitive impairment in Parkinson's disease. *J Neural Transm*. 2020;127(5):799-820. doi:10.1007/s00702-019-02113-w
15. Hayes MT. Parkinson's Disease and Parkinsonism. *Am J Med*. 2019;132(7):802-807. doi:10.1016/j.amjmed.2019.03.001
16. Anglade P, Vyas S, Javoy-Agid F, et al. Apoptosis and autophagy in nigral neurons of patients with Parkinson's disease. *Histol Histopathol*. 1997;12(1):25-31.

17. Schapira AH, Jenner P. Etiology and pathogenesis of Parkinson's disease. *Mov Disord*. 2011;26(6):1049-1055. doi:10.1002/mds.23732
18. Reich SG, Savitt JM. Parkinson's Disease. *Med Clin North Am*. 2019;103(2):337-350. doi:10.1016/j.mcna.2018.10.014
19. Sveinbjornsdottir S. The clinical symptoms of Parkinson's disease. *J Neurochem*. 2016;139(S1):318-324. doi:10.1111/jnc.13691
20. Pfeiffer RF. Autonomic Dysfunction in Parkinson's Disease. *Neurotherapeutics*. 2020;17(4):1464-1479. doi:10.1007/s13311-020-00897-4
21. Aarsland D, Kurz MW. The epidemiology of dementia associated with Parkinson disease. *J Neurol Sci*. 2010;289(1-2):18-22. doi:10.1016/j.jns.2009.08.034
22. Haddad F, Sawalha M, Khawaja Y, Najjar A, Karaman R. Dopamine and Levodopa Prodrugs for the Treatment of Parkinson's Disease. *Molecules*. 2017;23(1):40. doi:10.3390/molecules23010040
23. Fahn S. The history of dopamine and levodopa in the treatment of Parkinson's disease: Dopamine and Levodopa in the Treatment of PD. *Mov Disord*. 2008;23(S3):S497-S508. doi:10.1002/mds.22028
24. Wirdefeldt K, Odin P, Nyholm D. Levodopa–Carbidopa Intestinal Gel in Patients with Parkinson's Disease: A Systematic Review. *CNS Drugs*. 2016;30(5):381-404. doi:10.1007/s40263-016-0336-5
25. Hoy SM. Levodopa/Carbidopa Enteral Suspension: A Review in Advanced Parkinson's Disease. *Drugs*. 2019;79(15):1709-1718. doi:10.1007/s40265-019-01201-1
26. Tan YY, Jenner P, Chen SD. Monoamine Oxidase-B Inhibitors for the Treatment of Parkinson's Disease: Past, Present, and Future. *J Park Dis*. 12(2):477-493. doi:10.3233/JPD-212976
27. Bidesi NSR, Vang Andersen I, Windhorst AD, Shalgunov V, Herth MM. The role of neuroimaging in Parkinson's disease. *J Neurochem*. 2021;159(4):660-689. doi:10.1111/jnc.15516
28. Elsworth JD. Parkinson's disease treatment: past, present, and future. *J Neural Transm Vienna Austria 1996*. 2020;127(5):785-791. doi:10.1007/s00702-020-02167-1
29. Ye H, Robak LA, Yu M, Cykowski M, Shulman JM. Genetics and Pathogenesis of Parkinson's Syndrome. *Annu Rev Pathol*. 2023;18:95-121. doi:10.1146/annurev-pathmechdis-031521-034145
30. Gandini S, Botteri E, Iodice S, et al. Tobacco smoking and cancer: a meta-analysis. *Int J Cancer*. 2008;122(1):155-164. doi:10.1002/ijc.23033
31. Ascherio A, Schwarzschild MA. The epidemiology of Parkinson's disease: risk factors and prevention. *Lancet Neurol*. 2016;15(12):1257-1272. doi:10.1016/S1474-4422(16)30230-7
32. Murray A, Traylor J. Caffeine Toxicity. In: *StatPearls*. StatPearls Publishing; 2025. Accessed July 27, 2025. http://www.ncbi.nlm.nih.gov/books/NBK532910/
33. Warburton DER, Bredin SSD. Health benefits of physical activity: a systematic review of current systematic reviews. *Curr Opin Cardiol*. 2017;32(5):541-556. doi:10.1097/HCO.0000000000000437
34. Fang X, Han D, Cheng Q, et al. Association of Levels of Physical Activity With Risk of Parkinson Disease: A Systematic Review and Meta-analysis. *JAMA Netw Open*. 2018;1(5):e182421. doi:10.1001/jamanetworkopen.2018.2421
35. Langeskov-Christensen M, Franzén E, Grøndahl Hvid L, Dalgas U. Exercise as medicine in Parkinson's disease. *J Neurol Neurosurg Psychiatry*. 2024;95(11):1077-1088. doi:10.1136/jnnp-2023-332974
36. Portugal B, Artaud F, Degaey I, et al. Association of Physical Activity and Parkinson Disease in Women. *Neurology*. 2023;101(4):e386-e398. doi:10.1212/WNL.0000000000207424
37. Alberts JL, Rosenfeldt AB. The Universal Prescription for Parkinson's Disease: Exercise. *J Park Dis*. 10(Suppl 1):S21-S27. doi:10.3233/JPD-202100
38. Wang Z, Myers KG, Guo Y, et al. Functional reorganization of motor and limbic circuits after exercise training in a rat model of bilateral parkinsonism. *PloS One*. 2013;8(11):e80058. doi:10.1371/journal.pone.0080058
39. Endurance exercise training promotes angiogenesis in the brain of chronic/progressive mouse model of Parkinson's Disease - Muhammed Al-Jarrah, Mohammad Jamous, Khalid Al Zailaey, Salameh O. Bweir, 2010. Accessed April 15, 2025. https://journals.sagepub.com/doi/10.3233/NRE-2010-0574
40. Globus M, Mildworf B, Melamed E. Cerebral blood flow and cognitive impairment in Parkinson's disease. *Neurology*. 1985;35(8):1135-1139. doi:10.1212/wnl.35.8.1135
41. Johansson H, Hagströmer M, Grooten WJA, Franzén E. Exercise-Induced Neuroplasticity in Parkinson's Disease: A Metasynthesis of the Literature. *Neural Plast*. 2020;2020:8961493. doi:10.1155/2020/8961493
42. Radder DLM, Lígia Silva de Lima A, Domingos J, et al. Physiotherapy in Parkinson's Disease: A Meta-Analysis of Present Treatment Modalities. *Neurorehabil Neural Repair*. 2020;34(10):871-880. doi:10.1177/1545968320952799
43. da Silva FC, Iop R da R, de Oliveira LC, et al. Effects of physical exercise programs on cognitive function in Parkinson's disease patients: A systematic review of randomized controlled trials of the last 10 years. *PloS One*. 2018;13(2):e0193113. doi:10.1371/journal.pone.0193113
44. Kwok JYY, Kwan JCY, Auyeung M, et al. Effects of Mindfulness Yoga vs Stretching and Resistance Training Exercises on Anxiety and Depression for People With Parkinson Disease: A Randomized Clinical Trial. *JAMA Neurol*. 2019;76(7):755-763. doi:10.1001/jamaneurol.2019.0534
45. Amara AW, Memon AA. Effects of Exercise on Non-Motor Symptoms in Parkinson's Disease. *Clin Ther*. 2018;40(1):8-15. doi:10.1016/j.clinthera.2017.11.004
46. Ellis TD, Colón-Semenza C, DeAngelis TR, et al. Evidence for Early and Regular Physical Therapy and Exercise in Parkinson's Disease. *Semin Neurol*. 2021;41(2):189-205. doi:10.1055/s-0041-1725133