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The Effects of Bicycling on Tremor and Bradykinesia in Patients with Idiopathic Parkinson's Disease

Abstract

Background: Parkinson's disease is a progressive neurodegenerative disorder usually presenting in the later years of life, resulting in tremors, bradykinesia, and difficulties with gait and balance. It affects nearly 1.5 million Americans with treatment costs approaching \$25 billion annually. However, these treatments have been known to become less effective over time and may even be associated with adverse side effects. With the progressive nature of the disease and possible decreasing or adverse effects from medications and surgical therapies, it is imperative to identify other methods of improving quality of life in these patients. The purpose of this systematic review is to determine if bicycling shows improvements in tremors and bradykinesia in patients living with idiopathic Parkinson's disease (IPD).

Methods: An exhaustive search of available medical literature was conducted using Medline-OVID, CINAHL, Evidence-Based Medicine Reviews Multifile, Web of Science, Physiotherapy Evidence-Based Database, and Google Scholar using the keywords: *Parkinson's disease, bicycling, neuroplasticity, and tremor*. Synonymous terms including *cycling, rehabilitation* and *exercise* were also searched to prevent any relevant articles from being overlooked. Articles were limited to English and human studies only. Articles were assessed for quality using GRADE criteria. No articles were excluded based on GRADE criteria.

Results: Three articles met the inclusion and exclusion criteria for the systematic review. One was a randomized control trial, one an observational study, and one a before-after pilot study with crossover. While not all articles showed statistical significance, all three articles demonstrated a positive correlation with bicycling therapy improving tremor and bradykinesia in patients with IPD.

Conclusion: This systematic review demonstrated a positive correlation between bicycling and improvements of gross motor function in patients living with IPD. There were many limitations to the studies available, and future research is warranted to further investigate due to the clinical significance shown.

Keywords: *Parkinson's disease, bicycling, cycling, exercise, rehabilitation, neuroplasticity, tremor*

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**The Effects of Bicycling on Tremor and Bradykinesia in Patients with
Idiopathic Parkinson's Disease**

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School of Physician Assistant Studies
Pacific University
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Biography

[Redacted for privacy]

Abstract

Background: Parkinson's disease is a progressive neurodegenerative disorder usually presenting in the later years of life, resulting in tremors, bradykinesia, and difficulties with gait and balance. It affects nearly 1.5 million Americans with treatment costs approaching \$25 billion annually. However, these treatments have been known to become less effective over time and may even be associated with adverse side effects. With the progressive nature of the disease and possible decreasing or adverse effects from medications and surgical therapies, it is imperative to identify other methods of improving quality of life in these patients. The purpose of this systematic review is to determine if bicycling shows improvements in tremors and bradykinesia in patients living with idiopathic Parkinson's disease (IPD).

Methods: An exhaustive search of available medical literature was conducted using Medline-OVID, CINAHL, Evidence-Based Medicine Reviews Multifile, Web of Science, Physiotherapy Evidence-Based Database, and Google Scholar using the keywords: *Parkinson's disease*, *bicycling*, *neuroplasticity*, and *tremor*. Synonymous terms including *cycling*, *rehabilitation* and *exercise* were also searched to prevent any relevant articles from being overlooked. Articles were limited to English and human studies only. Articles were assessed for quality using GRADE criteria. No articles were excluded based on GRADE criteria.

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Conclusion: This systematic review demonstrated a positive correlation between bicycling and improvements of gross motor function in patients living with IPD. There were many limitations to the studies available, and future research is warranted to further investigate due to the clinical significance shown.

Keywords: *Parkinson's disease*, *bicycling*, *cycling*, *exercise*, *rehabilitation*, *neuroplasticity*, *tremor*

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List of Abbreviations

AAC.....	Active Assisted Cycling
EOT.....	End of Training
EOT+4.....	4 Weeks After End of Training
FE.....	Forced Exercise
GRADE.....	Grading of Recommendations, Assessment, Development, and Evaluations
H & Y.....	Hoehn and Yahr Score
IPD.....	Idiopathic Parkinson's Disease
NNT.....	Number Needed to Treat
RPE.....	Rating of Perceived Exertion
RPM.....	Revolutions per Minute
UPDRS.....	Unified Parkinson's Disease Rating Scale
VE.....	Voluntary Exercise
Vo ₂ max.....	Estimated Maximum Oxygen Consumption

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The Effects of Bicycling on Tremor and Bradykinesia in Patients with Idiopathic Parkinson's Disease

BACKGROUND

Idiopathic Parkinson's disease (IPD) is a progressive neurodegenerative disorder usually presenting in the later years of life. The condition is due to the selective neuronal loss of substantia nigra and a decrease in dopamine production in the basal ganglia,^{1,2} resulting in tremors, bradykinesia, and difficulties with gait and balance.³ It affects nearly 1.5 million Americans with treatment costs approaching \$25 billion annually.¹ Standard therapies today for the treatment of IPD include pharmacological interventions, such as amantadine, monoamine oxidase B (MAO-B) inhibitors, catechol-o-methyltransferase (COMT) inhibitors, dopamine agonists and levodopa, along with surgical techniques such as deep brain stimulation and pallidotomy. However, these treatments have been known to become less effective over time and may even be associated with adverse side effects.⁵ Due to the progressive nature of the disease and the possible decreasing effects of medications, along with the possible adverse effects of these pharmacological and surgical therapies, it is imperative to identify other methods of improving quality of life in patients living with idiopathic Parkinson's disease.

In the past, exercise was not recommended as a source of rehabilitative therapy for patients with IPD, as it was thought to have no measurable effect on IPD symptoms and may even create worsening effects of the underlying condition.⁶ However in numerous recent studies,⁷⁻¹¹ exercise has been shown to produce improvements in motor function and muscle strength, and also create changes in neuroplasticity after bouts of exercise in many forms, including aerobic, resistance and balance training. Physical

activity, especially in the form of acute exercise and training modalities, seem to be key interventions to trigger the process of neurotrophin-mediated energy metabolism, and in turn, neural plasticity.¹⁰ These alterations of neuroplasticity within the CNS in response to exercise include processes of neurogenesis, synaptogenesis, and molecular adaptations.¹² This in mind, these insights are suggestive that exercise may be a novel treatment capable of reversing or delaying disease progression of IPD.² By altering dopaminergic availability, exercise may play a more critical role in maintaining these normal synaptic connections rather than just substituting the dopamine lost via pharmacological agents alone.¹³ This theory has not yet been measured on humans, but suggests that high-intensity and forced exercise could trigger endogenous release of neurotrophic factors or dopamine. Despite the research that has already been done, however, it is difficult to identify a “one-type-fits-all” approach to physical activity therapy due to the severity of IPD symptoms among individuals.¹⁵

With the progressive neurodegeneration of Parkinson’s disease and the high annual costs of medications and elective surgeries to improve the quality of life in those living with IPD, it is imperative to identify rehabilitative strategies that may help minimize the effects of IPD. Specifically, bicycling came to light as a possible exercise therapy after author, J. Alberts, captained (front seat) a week-long, cross-country, tandem-bicycle recreational trip with a friend who was diagnosed with IPD. After only two days of riding, the patient noticed improvements in her symptoms and a significant improvement was displayed in her handwriting.¹ The purpose of this study is to conduct a systematic review of the literature on patients with Parkinson’s disease and the effects bicycling has on improving tremors and bradykinesia in those living with IPD.

METHODS

An exhaustive search of available medical literature was conducted using Medline-OVID, CINAHL, Evidence-Based Medicine Reviews (EBMR) Multifile, Web of Science, Physiotherapy Evidence-Based Database (PEDro), and Google Scholar using the keywords: *Parkinson's disease*, *bicycling*, *neuroplasticity*, and *tremor*. Synonymous scientific terms including *cycling*, *rehabilitation*, and *exercise* were also searched to prevent any relevant articles from being overlooked.

Articles were considered for inclusion in the review if they met criteria of English language and conducted on humans. The bibliographies of the articles were further reviewed to search for any other relevant sources. Articles with primary data evaluating patients with idiopathic Parkinson's disease, bicycling as the therapy and effects on tremors and gross motor function were chosen. Studies were not limited by publication date. A search using the National Institute of Health clinical trials site showed two clinical trials^{16,17} currently recruiting for studies involving Parkinson's disease and bicycling research.

The articles reviewed were critically appraised and evaluated using the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) for validity.¹⁸ Each article was placed in a category of "High", "Medium", "Low", or "Very Low", based on the quality of evidence.

RESULTS

Initial results of the search provided a total of 340 articles for review. After screening relevant articles for the inclusion/exclusion criteria listed in the methods, three

studies met the criteria.^{4,14,15} One study was a randomized control trial,¹⁴ one an observational trial,⁴ and the last a before-after pilot trial with cross-over¹⁵ (see Table I).

Ridgel et al, 2009

Ridgel et al, 2009,¹⁴ was a single-blinded, randomized control trial that was one of the first studies exploring the effects of bicycling as a therapy to decrease the symptoms of tremor and bradykinesia in those living with Parkinson's disease.¹⁴

Ten patients with idiopathic Parkinson's disease (IPD), eight men and two women, meeting all inclusion criteria were randomly assigned to complete an 8-week intervention of either forced exercise (FE) or voluntary exercise (VE). Five patients were randomized to the FE (treatment) group and five patients to the VE (control) group. The inclusion criteria for the study required patients to have IPD and be on the anti-IPD medication, levodopa.¹⁴

All patients completed three 1-hour exercise sessions per week for eight weeks, consisting of a 10-minute warm-up, a 40-minute exercise set of FE or VE, and a 10-minute cool-down; 2-5 minute breaks were given if needed during the 40-minute exercise set in the initial two weeks of study, then encouraged to continue exercising in the ensuing six weeks of study. To control for any discrepancies owing to fitness, each group was instructed to stay within their target heart rate (T_{HR}) using the Karnoven formula. The VE group exercised on a stationary single bicycle and was instructed to pedal at their preferred voluntary rate, maintaining their heart rate within T_{HR} . The FE group exercised with a trainer on a stationary tandem bicycle, maintaining a pedaling rate between 80-90 revolutions per minute (rpm), or 30% more than their VE rate, and also maintaining their heart rate within their T_{HR} . All patients were encouraged to increase

their heart rate range by 5% every two weeks. Both FE and VE groups remained constant on their anti-IPD medications throughout the study.¹⁴

Prior to beginning the study, each participant had baseline assessments for fitness using the YMCA submaximal cycle ergometer test to estimate maximal oxygen uptake (Vo_2max) and motor and manual dexterity using the Unified Parkinson's Disease Rating Scale (UPDRS) Part III²⁰ while OFF anti-IPD medications for 12 hours. An experienced movement disorders neurologist was blinded to the UPDRS Part III motor exam and manual dexterity assessments of the participants. These assessments were performed on three occasions: pretreatment (baseline), end of treatment (EOT), and four weeks after treatment (EOT+4).¹⁴

At baseline, the age, duration of IPD, fitness and initial UPDRS III scores while OFF anti-IPD medication were comparable between both groups. The total work produced by the patients and the T_{HR} during the exercise intervention did not differ between the groups. Average cadence in the FE group was significantly greater (30%) than in the VE group ($p = .002$). Aerobic capacity improved by 11% and 17% for the FE and VE groups, respectively, but showed no statistical significance between the groups. UPDRS III scores improved by 35% from baseline to EOT for the FE group ($p = .002$), whereas no improvements were seen in the VE group ($p > 0.17$). Four weeks after exercise cessation (EOT+4), the UPDRS was 11% less than baseline for the FE group and approached significance ($p = 0.09$). The VE group had similar UPDRS scores from baseline and EOT+4. Importantly noted, improvements in each UPDRS motor subscale varied from patient to patient during the EOT+4 time period, but across the FE group, rigidity improved by 41%, tremor improved by 38%, and bradykinesia improved by 28%

after eight weeks of FE. The data for tremors demonstrate 100% of patients in the FE group showed an improvement in their tremor, whereas only 40% of patients in the VE group noticed improvement. This results in a calculated NNT = 1 and RR = 2.5 for tremor. The data for bradykinesia showed that 100% of patients in the FE group had improvements in bradykinesia, while again only 40% of patients in the VE group had improvements. The calculated NNT and RR were the same as above at 1 and 2.5, respectively (see Table II).¹⁴

Prior to exercise, coupling of grasping forces was irregular and inconsistent in both groups. However, following FE the grip-load profile plots were more consistent and increased in a more linear fashion for both limbs, whereas no changes were noted in coupling of grasping forces in the VE group. Interlimb coordination, as assessed by grip time delay, improved significantly for the FE group but did not change for the VE group ($p = 0.015$). The FE group displayed a significant increase in rate for grip force of the manipulating limb ($p = 0.006$), whereas a slight decrease was observed for the VE group ($p = 0.405$). These improvements in the coupling of grasping forces, interlimb coordination, and rate of force production indicate that manual dexterity was improved for patients in the FE group compared to those in the VE group.¹⁴

As stated by the authors, limitations of this study included UPDRS scoring as rather limited in range and also its subjective scoring scale, albeit the scoring was performed by an experienced movement disorders neurologist who was blinded to the study. The small sample size of 10 patients being studied makes for serious limitations in data analysis and interpretation, and one of those 10 patients were lost to follow up without an explanation.¹⁴

Ridgel et al, 2011

Ridgel et al, 2011,⁴ was a single-blinded observational study encompassing 32 patients (22 men and 10 women) with IPD with the objective of measuring passive leg cycling in IPD symptoms. Eligibility criteria for each patient consisted of a diagnosis of IPD, passing a cardiovascular fitness examination, being on an anti-IPD medication, and not requiring the use of assistance devices. Exclusion criteria of patients for the study were contraindications to exercise, such as stroke, cardiovascular disease, or musculoskeletal injuries.⁴

The first 20 patients were assigned as part of the cycling group (treatment) and participated in three consecutive weekly sessions of bicycling while off anti-IPD medications after an overnight withholding period (8-12 hours). Each session consisted of a 5-minute warm-up at 40 rpms, a 30-minute passive cycling of leg rotation speeds at randomized rpms of 60, 70, or 80, plus a 5-minute cool-down at 40 rpms done on a motorized cycle (MOTOmed Viva 2 Movement Therapy Trainer). Subjects were instructed to not resist and allow the motor to freely rotate their legs. All sessions were completed between 9am or 10am on the same day each week. Functional assessments of upper extremity motor function for the treatment group were conducted immediately before and within 10 minutes after each bout of passive leg cycling. The 12 control subjects reported to the laboratory for a single session to assess upper motor extremity function while off anti-IPD medications after an 8-12 hour overnight withholding. The control group was assessed before and after watching a short instructional video about the MOTOmed motorized cycle. The KinesiaTM device was used to collect kinematic data to

evaluate tremor and bradykinesia of the more affected upper limb in both the control and treatment groups.⁴

At baseline, characteristics of all subjects from both control and cycling groups were not significantly different (height, weight, age, Hoehn & Yahr stage,¹⁹ and duration of IPD). The power output from the MOTOMed computer was 0 watts in all trials, which suggested complete passive leg cycling in all subjects. Passive leg cycling also demonstrated no significant increase in heart rate among the warm-up, main set, and cool-down. Kinesia scores for the resting, postural, and tremor tests were summed for analysis. In the treatment group, 12 (63%) of 19 cycling subjects showed an improvement in tremor, whereas only three (25%) of 12 individuals showed a positive change in the control group. Bradykinesia analysis was based on UPDRS III motor scores²⁰ of items 24 (hand grasp) and 25 (pronation/supination) while wearing Kinesia™ on the more affected hand. During the hand grasp task, 14 (70%) of 20 passive cycling subjects showed improvement, while only four (33%) of 12 control subjects showed improvement in frequency. For analysis of pronation/supination task, 18 (90%) of 20 passive cycling subjects demonstrated increased movement frequency, whereas only three (25%) of 12 individuals in the control group showed improvement. Results for this study demonstrated that 63% of patients in the treatment group showed an improvement in their tremor, versus only 25% of patients in the control group showing tremor improvement. This resulted in a NNT of 2 in this study, with an RR of 2.53. The data calculated for bradykinesia demonstrated similar effects. The treatment group demonstrated a 70% improvement, while the control group only showed a 33%

improvement in bradykinesia. Again, NNT and RR were both similar for bradykinesia calculations of 2 and 2.12, respectively (see Table II).⁴

The authors stated that there were numerous limitations to this observational study, one of those being a small population sample size of 32 individuals. However, none of the participants were lost to follow up, and the trial was not stopped early. Motor function data was, however, collected by unblinded staff, but subjective UPDRS scoring analysis was done by blinded staff. Also, many of the participants had only mild tremors, which was difficult to detect changes in motor function using the assessment methods. Furthermore, the research team suggested that bradykinesia is extensively more complex to analyze than tremor since it is a voluntary task and can have more inter- and intrasubject variability overall.⁴

Ridgel et al, 2012

This third study of Ridgel et al, 2012,¹⁵ was a before-after pilot trial with cross-over, no blinding, and no control group. Ten individuals with IPD (four men and six women) were recruited for a study on active-assisted cycling (AAC) using a commercially available motorized cycle trainer. Eligibility criteria for this study included a diagnosis of IPD and Hoehn & Yahr stages 1 to 3 (see Appendix A).¹⁹ Patients were excluded if there were contraindications to exercise such as cardiovascular disease, musculoskeletal injuries, stroke, or dementia.¹⁵

Each of the 10 participants visited the laboratory on two separate occasions. During the first visit, cardiovascular fitness and motor function while on anti-IPD medications were tested. The second visit, all participants performed a single bout of AAC exercise while off anti-IPD medications after an overnight withholding of 8-12

hours. The single bout of AAC included a 5-minute warm-up at 40-50 rpms, 30-minutes of AAC at 80-85 rpms, and a 5-minute cool-down at 40-50 rpms.¹⁵

The YMCA submaximal cycle ergometer test was used to estimate cardiovascular fitness, or Vo_2max . During AAC, the motor speed was set at 75 rpms and participants were asked to pedal at a rate of 80-85rpms for the 30-minute AAC bout; this paradigm was developed to mimic the FE tandem bicycle exercise from Ridgel et al, 2009.¹⁴ If patients were unable to pedal at 80-85 rpms, the motor would take over and move the legs at 75 rpms. The tremor and bradykinesia assessments were performed immediately before and within 10 minutes of exercise cessation using the KinesiaTM device to evaluate the more affected upper limb.¹⁵

All 10 participants were able to complete the AAC exercise session, with a rate of perceived exertion (RPE) after exercise as being slightly elevated (9.6) from warm-up levels (7.0), suggesting participants tolerated exercise well and did not have excessive fatigue after completing the 30-minute bout of AAC. Regarding tremor and bradykinesia scores, although there was a large variability in baseline tremor among the participants, seven participants (78%) exhibited improvements in their summed tremor score in the OFF medication post-AAC state. The averaged data demonstrates a significant increase in summed tremor scores from the ON medication state to the OFF pre-AAC state ($p = 0.03$). Although there was no statistical significance between tremor scores of pre- and post-AAC levels, 40 minutes of AAC results in a decrease in tremor that was not significantly different from that measured in the ON medication state ($p = 0.83$) (See Figure 1). Bradykinesia analysis demonstrated an improvement in movement speed from OFF pre-AAC to OFF post-AAC ($p = <0.001$) and a worsening in movement speed from

the ON state to the OFF pre-AAC state ($p = <0.001$), with no significant differences in movement speed between the ON medication state and the OFF medication post-AAC state ($p = 0.303$) (see Figure 2). Data of one participant was lost due to computer error.¹⁵

There were a few limitations to this study that were identified by the authors. One of the major limitations again, was the small sample population size of 10 individuals. Within these 10 individuals was also a wide-variety of IPD symptom severity, which created limitations in comparisons of data analysis. Another limitation was the possibility of a delayed effect of AAC that was not analyzed due to the immediate follow up analysis within 20 minutes of AAC cessation. Lastly, there may be discrepancies in data analysis from timing of exercise throughout the daily sessions, which could have had an effect among patient outcomes.¹⁵

DISCUSSION

Research on the effects of exercise in patients living with idiopathic Parkinson's disease is only in the beginning stages of work, especially when it comes to testing specifically the effects bicycling has on the motor functions within IPD. There are very few studies on this particular topic, and within these studies are many limitations. However, each of the studies available demonstrates positive effects of bicycling on decreasing tremor and improving bradykinesia in patients living with IPD.

The preliminary study in 2009 from Ridgel et al¹⁴ demonstrated that eight weeks of FE produced significant global improvements in IPD motor symptoms, compared to patients completing VE. The secondary outcome of the trial showed an improvement in aerobic fitness for IPD patients for both FE and VE groups. Therefore, the clinical data from this initial study suggests the effects of FE are not just transitory but may be

maintained, granted to a lesser degree than immediate effects. Another important finding from this study¹⁴ was that the levels of rigidity were the same or better for all patients in the FE group after exercise cessation in comparison to their baseline rigidity; and although the numbers calculated by the research team were not statistically significant, there is clinical significance for both tremor and bradykinesia outcomes from this study as demonstrated by the NNTs (1 and 1, respectively) and RRs (2.5 and 2.5, respectively) for both. There is monumental clinical significance with an NNT = 1, indicating that every patient treated with FE will benefit, both in their tremor and bradykinesia scores. The RR values of 2.5 for tremor and bradykinesia suggest that a patient is twice as likely to benefit in both their tremor and bradykinesia scores from FE versus VE.

The second study performed by the team Ridgel et al in 2011,⁴ was a piggyback off of the first study to see whether or not acute bouts of passive leg cycling would have positive effects on improving upper extremity tremor and bradykinesia. The primary finding from this study did show that with passive leg cycling, patients with IPD had improvements in the most affected upper extremity tremor and bradykinesia immediately after a 30-minute bout of passive leg cycling. When the data was pooled, passive leg cycling resulted in significant improvement of upper extremity tremor and bradykinesia in comparison to the control group. However, there was no significant difference among the randomized pedaling rates of patients. With these findings, it is interesting to note that lower extremity passive cycling can promote changes of upper extremity IPD motor symptoms. This is of importance for those patients that may have limited mobility due to their IPD, or are confined to wheelchairs and cannot actively exercise. Again, there is significant clinical importance as demonstrated by NNT = 2 for both tremor and

bradykinesia in this study. This implies that passive cycling is an effective therapy for both tremor and bradykinesia in patients with IPD. The RR values for tremor and bradykinesia (2.53 and 2.12, respectively) both suggest that a patient is twice as likely to benefit from passive leg cycling therapy for the improvement of their tremor and bradykinesia symptoms.

The final published study by Ridgel et al, 2012,¹⁵ was again, a piggyback off of the first study¹⁴ by replacing the FE via a tandem training partner to instead using AAC. As previously stated, all of the 10 participants to the study were able to tolerate the 30 minute bout of AAC well, with no excess fatigue afterward. These findings demonstrate that PD patients can tolerate AAC well while off their anti-IPD medication, and that a single bout of AAC can improve their tremor and bradykinesia. The team also conducted anecdotal interviews with each participant at the end of the AAC session with findings suggesting many of them felt better later in the day after their bout of AAC exercise. An important mention of the data analysis for this particular study is this research with AAC filled a gap in literature by demonstrating similar improvements in tremor and bradykinesia between the use of cycling as an intervention in comparison to pharmacological medication for individuals with IPD, without the use of a harness system or trainer.¹⁵

Quality of Evidence

Assessment for quality of each study was done using the GRADE assessment tool (see Table 1).¹⁶ All three of the reviewed articles were initially down graded due to small sample sizes, which can compromise validity. Ridgel et al, 2009,¹⁴ was initially graded at a high level of “Medium” due to being a randomized control trial, but again, was down

graded to a level of “Very Low” due to its small sample size of 10 individual participants, one of which was lost to follow up, having only single blinding, and some inconsistencies with variability in results. Even though this study produced an NNT = 1 for both tremor and bradykinesia, along with an RR = 2.5 for both tremor and bradykinesia, this study was unable to be upgraded due to its initial GRADE of “Very Low” (see Table I).

Both Ridgel et al, 2011,⁴ and 2012,¹⁵ began as “Low” studies due to being an observational and before-after pilot study, respectively. Again, with small sample populations, these were down graded even further. Although Ridgel et al, 2011,⁴ had a large magnitude of effect with an NNT = 2 for both tremor and bradykinesia, and also RR = 2.53 and 2.12, respectively, upgrading was not possible due to the GRADE criteria and therefore received a final GRADE of “Very Low.” Ridgel et al, 2012,¹⁵ also remained at a level of “Very Low” (see Table I).

Recommendations for Future Studies

In order to answer the question of whether bicycling produces positive effects on tremors and bradykinesia in patients living with idiopathic Parkinson’s disease, further research is warranted. Large sample populations in a randomized control trial setting would be the most appropriate to better validate results. Some considerations for future studies include using patients with higher UPDRS III motor scores at baseline and not only examining the effects of bicycling in comparison to other forms of aerobic, resistance, and balance exercises, but also the duration of the motor benefits provided. Other quantifiable measures that should be included in future research should be measuring neurotrophic factors pre- and post-exercise, the effects on biomechanical measures of lower extremity function and postural stability, and also the effects of

treatment versus control groups of off- and on-medication states, respectively. Another important note for future research is whether it is purely the physical activity of bicycling that is showing improvement, or whether it is the rhythm and cadence of the movement that leads to these improvements in IPD patients.¹¹

CONCLUSION

Although much research currently available has proven the beneficial effects of exercise in healthy adults, there is still much to be done regarding the effects of exercise on motor function symptoms in patients with IPD, especially that of bicycling. With the minimal research currently available on this topic and the positive benefits demonstrated in each of the three studies,^{4,14,15} it is quite evident that bicycling is not only beneficial for improvements of IPD symptoms such as tremors and bradykinesia, but also beneficial for cardiovascular fitness. This has the potential to be important when considering exercise as either monotherapy, or as an adjunct with pharmacological and/or surgical therapies, for the improvement of symptoms in patients with IPD with little risk of precipitating adverse effects.

A better understanding of the neuroprotection and neurorestoration of the particular types of bicycling therapies discussed is an important focus for future research to be able to use as an adjunct with pharmacological and surgical therapies with minimal risks or side effects that are currently documented as beneficial to this disease. However, none of this can be determined until further, large scale randomized control trials are performed. It is conclusive that exercise is beneficial to the global population, but to what extent bicycling exercise has on the improvement of gross motor functions in patients living with idiopathic Parkinson's disease is yet to be determined. This

systematic review did, however, demonstrate a positive correlation between bicycling and improvements of gross motor function in patients living with IPD.

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Table I. Characteristics of Reviewed Studies

Quality Assessment					No of Patients		Quality
Design	Limitations to quality	Inconsistency	Indirectness	Imprecision	Treatment	Control	
Ridgel A, Vitek J, Alberts J. Forced, not voluntary, exercise improves motor function in Parkinson's Disease patients. <i>Neurorehabil Neural Repair</i> . 2009;23:600.							
Randomized Control Trial	Serious limitations ^a	No serious inconsistencies	No indirectness	Serious imprecision ^b	5	5	☐000 Very Low
Ridgel AL, Muller MD, Kim CH, Fickes EJ, Mera TO. Acute effects of passive leg cycling on upper extremity tremor and bradykinesia in Parkinson's disease. <i>Phys Sportsmed</i> . 2011;39:83-93.							
Observational	No serious limitations	No serious inconsistencies	No serious indirectness	Serious imprecision ^b	20	12	☐000 Very Low
Ridgel AL, Peacock CA, Fickes EJ, Kim CH. Active-assisted cycling improves tremor and bradykinesia in Parkinson's disease. <i>Arch Phys Med Rehabil</i> . 2012;93:2049-2054.							
Before-after pilot study with cross-over	Serious limitations ^c	No serious inconsistencies	No serious indirectness	No serious imprecision	10	—	☐000 Very Low

^aOne of the ten patients lost to follow up

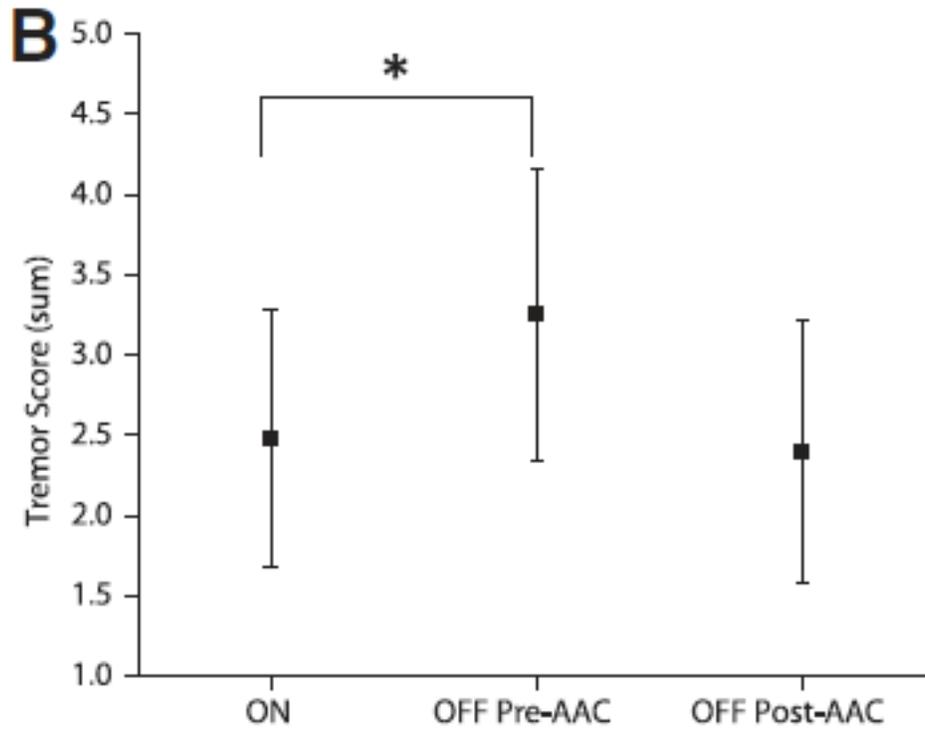
^bSmall sample size

^cNo control group

Table II. Summary of Findings

The Effects of Bicycling on Tremor and Bradykinesia in Patients with Parkinson's Disease							
Patient: patients who have diagnosed Idiopathic Parkinson's Disease							
Intervention: bicycling							
Outcome: improvement of tremor and bradykinesia							
Author/year	Participants/ Design	Duration of Study	Type of Bicycling Therapy	Tremor	Bradykinesia	Tremor NNT/ RR	Bradykinesia NNT/ RR
Ridgel et al (2009)	10 Randomized Control Trial	8 weeks of FE	Forced Exercise	Significant improvement	Significant improvement	1/ 2.5	1/ 2.5
		8 weeks of VE	Voluntary Exercise	No significant improvement	No significant improvement	—	—
Ridgel et al (2011)	32 Observational	3 weeks of PLC	Passive Leg Cycling	Significant improvement	Significant improvement	2/ 2.53	2/ 2.12
		1 single session	Watch short instructional video on passive leg cycling MOTomed	No significant improvement	No significant improvement	—	—
Ridgel et al (2012)	10 Before-after pilot trial with cross-over	2 separate occasions = baseline and single AAC	Active Assisted Cycling	Significant improvement	Significant improvement		

Figure 1. Tremor scores using Kinesia™



Average tremor scores of 9 participants with PD. There was a significant increase in tremor score between the ON and OFF pre-AAC medication states. OFF post-AAC tremor scores were similar to ON medication scores. Error bars indicate standard error of the mean. * $P < .05$.

*Used with permission from author¹⁵

Figure 2. Bradykinesia scores using Kinesia™

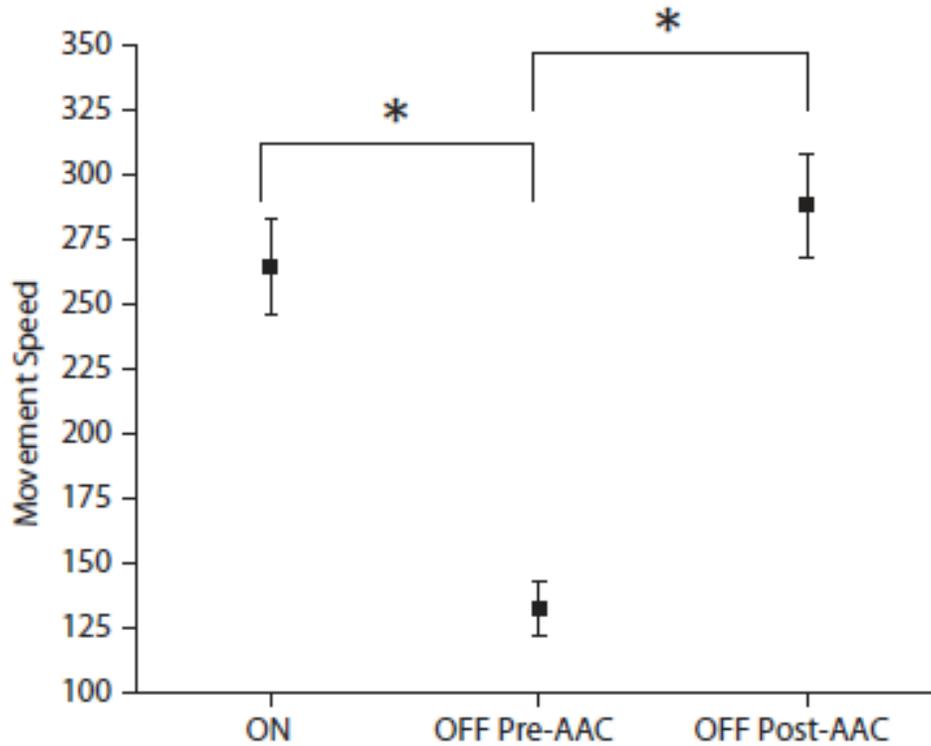


Fig 3. Bradykinesia variables as measured with Kinesia. Average movement speed of 9 participants with PD. There was a significant decrease in movement speed between the ON and OFF pre-AAC medication states. OFF post-AAC movement speed was similar to ON medication scores. * $P < .001$.

*Used with permission from author¹⁵

Appendix A. Hoehn and Yahr Scale

Hoehn and Yahr Staging of Parkinson's Disease¹⁹

1. Stage One
 1. Signs and symptoms on one side only
 2. Symptoms mild
 3. Symptoms inconvenient but not disabling
 4. Usually presents with tremor of one limb
 5. Friends have noticed changes in posture, locomotion and facial expression
2. Stage Two
 1. Symptoms are bilateral
 2. Minimal disability
 3. Posture and gait affected
3. Stage Three
 1. Significant slowing of body movements
 2. Early impairment of equilibrium on walking or standing
 3. Generalized dysfunction that is moderately severe
4. Stage Four
 1. Severe symptoms
 2. Can still walk to a limited extent
 3. Rigidity and bradykinesia
 4. No longer able to live alone
 5. Tremor may be less than earlier stages
5. Stage Five
 1. Cachectic stage
 2. Invalidism complete
 3. Cannot stand or walk
 4. Requires constant nursing care

Appendix B. UPDRS III Motor Exam

III. MOTOR EXAMINATION²⁰

18. Speech

- 0 = Normal.
- 1 = Slight loss of expression, diction and/or volume.
- 2 = Monotone, slurred but understandable; moderately impaired.
- 3 = Marked impairment, difficult to understand.
- 4 = Unintelligible.

19. Facial Expression

- 0 = Normal.
- 1 = Minimal hypomimia, could be normal "Poker Face".
- 2 = Slight but definitely abnormal diminution of facial expression.
- 3 = Moderate hypomimia; lips parted some of the time.
- 4 = Masked or fixed facies with severe or complete loss of facial expression; lips parted 1/4 inch or more.

20. Tremor at rest (head, upper and lower extremities)

- 0 = Absent.
- 1 = Slight and infrequently present.
- 2 = Mild in amplitude and persistent. Or moderate in amplitude, but only intermittently present.
- 3 = Moderate in amplitude and present most of the time.
- 4 = Marked in amplitude and present most of the time.

21. Action or Postural Tremor of hands

- 0 = Absent.
- 1 = Slight; present with action.
- 2 = Moderate in amplitude, present with action.
- 3 = Moderate in amplitude with posture holding as well as action.
- 4 = Marked in amplitude; interferes with feeding.

22. Rigidity (Judged on passive movement of major joints with patient relaxed in sitting position. Cogwheeling to be ignored.)

- 0 = Absent.
- 1 = Slight or detectable only when activated by mirror or other movements.
- 2 = Mild to moderate.
- 3 = Marked, but full range of motion easily achieved.
- 4 = Severe, range of motion achieved with difficulty.

23. Finger Taps (Patient taps thumb with index finger in rapid succession.)

- 0 = Normal.
- 1 = Mild slowing and/or reduction in amplitude.
- 2 = Moderately impaired. Definite and early fatiguing. May have occasional arrests in movement.
- 3 = Severely impaired. Frequent hesitation in initiating movements or arrests in ongoing movement.
- 4 = Can barely perform the task.

24. Hand Movements (Patient opens and closes hands in rapid succession.)
- 0 = Normal.
 - 1 = Mild slowing and/or reduction in amplitude.
 - 2 = Moderately impaired. Definite and early fatiguing. May have occasional arrests in movement.
 - 3 = Severely impaired. Frequent hesitation in initiating movements or arrests in ongoing movement.
 - 4 = Can barely perform the task.
25. Rapid Alternating Movements of Hands (Pronation-supination movements of hands, vertically and horizontally, with as large an amplitude as possible, both hands simultaneously.)
- 0 = Normal.
 - 1 = Mild slowing and/or reduction in amplitude.
 - 2 = Moderately impaired. Definite and early fatiguing. May have occasional arrests in movement.
 - 3 = Severely impaired. Frequent hesitation in initiating movements or arrests in ongoing movement.
 - 4 = Can barely perform the task.
26. Leg Agility (Patient taps heel on the ground in rapid succession picking up entire leg. Amplitude should be at least 3 inches.)
- 0 = Normal.
 - 1 = Mild slowing and/or reduction in amplitude.
 - 2 = Moderately impaired. Definite and early fatiguing. May have occasional arrests in movement.
 - 3 = Severely impaired. Frequent hesitation in initiating movements or arrests in ongoing movement.
 - 4 = Can barely perform the task.
27. Arising from Chair (Patient attempts to rise from a straight-backed chair, with arms folded across chest.)
- 0 = Normal.
 - 1 = Slow; or may need more than one attempt.
 - 2 = Pushes self up from arms of seat.
 - 3 = Tends to fall back and may have to try more than one time, but can get up without help.
 - 4 = Unable to arise without help.
28. Posture
- 0 = Normal erect.
 - 1 = Not quite erect, slightly stooped posture; could be normal for older person.
 - 2 = Moderately stooped posture, definitely abnormal; can be slightly leaning to one side.
 - 3 = Severely stooped posture with kyphosis; can be moderately leaning to one side.
 - 4 = Marked flexion with extreme abnormality of posture.
29. Gait
- 0 = Normal.
 - 1 = Walks slowly, may shuffle with short steps, but no festination (hastening

steps) or propulsion.

2 = Walks with difficulty, but requires little or no assistance; may have some festination, short steps, or propulsion.

3 = Severe disturbance of gait, requiring assistance.

4 = Cannot walk at all, even with assistance.

30. Postural Stability (Response to sudden, strong posterior displacement produced by pull on shoulders while patient erect with eyes open and feet slightly apart. Patient is prepared.)

0 = Normal.

1 = Retropulsion, but recovers unaided.

2 = Absence of postural response; would fall if not caught by examiner.

3 = Very unstable, tends to lose balance spontaneously.

4 = Unable to stand without assistance.

31. Body Bradykinesia and Hypokinesia (Combining slowness, hesitancy, decreased armswing, small amplitude, and poverty of movement in general.)

0 = None.

1 = Minimal slowness, giving movement a deliberate character; could be normal for some persons. Possibly reduced amplitude.

2 = Mild degree of slowness and poverty of movement which is definitely abnormal. Alternatively, some reduced amplitude.

3 = Moderate slowness, poverty or small amplitude of movement.

4 = Marked slowness, poverty or small amplitude of movement.