Systematic Review

Does assisted cycling improve function in those with Parkinson's disease?

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Abstract

Background: Functional decline is a cardinal sign of Parkinson's disease (PD), a neurodegenerative disease that affects 1% of individuals over the age of 60. Physical symptoms have a detrimental effect on activities of daily living and quality of life. High intensity exercise has enhanced neuroplasticity and reduced the rate of dopaminergic cell loss in animal studies. One form of high intensity exercise is assisted cycling, which has been shown to be effective for those with other neurological disorders. There is no consensus as to the efficacy in those with PD.
Objective: To explore the efficacy of assisted cycling in improving motor function in people with PD.
Method: A systematic search of PsycINFO, ScienceDirect, SPORTDiscus, CINAHL, arXiv, MEDLINE and Web of Science was conducted, including articles from January 2003 to October 2016. Studies were assessed for quality using a critical appraisal tool. No articles were excluded due to quality.
Results: Seven studies were included in this review, with a total sample of 179 participants with a diagnosis of PD. Four studies were randomised control trials, the others included two case control trials, and a single-subject design trial. The level of cycle assistance, length of intervention and sessions varied between studies. All interventions showed improvements in motor function, with a greater effect on those with more advanced PD.
Conclusion: There is moderate evidence to show the efficacy of assisted cycling in improving global motor function in individuals with PD. Future research is required to determine optimum assisted cycling interventions in terms of frequency, duration of

sessions and length. The long-term effects of assisted cycling should also be explored in future research.

Keywords: Parkinson's disease; Neurological; Motor function; Intervention; Forced; Assisted cycling

1. Introduction

Parkinson's disease (PD) is the second most prevalent neurodegenerative disorder, affecting 1% of individuals over the age of 60 in industrialised countries.[1] In the UK, the total cost of PD has been estimated between £449 million and £3.3 billion annually.[2]

PD is characterised by the degeneration of dopaminergic pathways in the basal ganglia, contributing to a variety of symptoms that impact quality of life.[3] Some of these relate to motor functional deficits, including: bradykinesia, tremor, rigidity and postural instability.[4] These physical symptoms have a detrimental effect on activities of daily living and quality of life.[5,6]

The medical management of PD commonly uses a pharmacological approach but this is expensive and may lead to undesirable side effects, which impact on quality of life.[7] The development of non-pharmacological approaches, such as exercise, are suggested to be a more favourable option in those with PD because they can be used to address activities of daily living and thus improve quality of life.[8] Exercise has been beneficial in the management of PD symptoms,[9-12] with increasing evidence that the speed and intensity of the exercise may be an important factor.[13]

Forced exercise (FE) is a form of high intensity exercise where an individual is forced to maintain a higher than preferred cadence, either passively or actively assisted.[14] Animal studies have shown that high intensity exercise can enhance neuroplasticity and reduce the rate of dopaminergic cell loss, as well as improving motor function.[13,15,16] There are a number of modes of exercise that are employed to encourage high intensity exercise in those with neurological conditions. These include body weight supported treadmill training (BWSTT) and assisted cycling.

BWSTT allows those with neurologically limiting conditions, including PD, to achieve a higher than preferred cadence.[17] However, the application of BWSTT is limited for those with PD because of the equipment required, the need for constant supervision, and the practicality of its use in both clinical and home settings.[18]

Assisted cycling has been shown to improve motor function in those following strokes.[19-21] Yet, there is limited research relating to the efficacy of assisted cycling for those with PD. However, Alberts *et al.*[8] describe an occasion where an individual with PD was led on a tandem bicycle ride across Iowa and subsequently exhibited a substantial improvement in handwriting.

The aim of this review is to investigate the efficacy of assisted cycling in improving motor function in people with PD.

2. Methods

2.1 Search strategy

A search was conducted in seven online databases (PsycINFO, ScienceDirect, SPORTDiscus, CINAHL, arXiv, MEDLINE and Web of Science) in October 2016, to identify relevant studies. A Boolean search strategy, with key terms and their synonyms, were entered in search databases (Table 1). First, articles were screened for eligibility by their titles and abstracts. Full texts of articles were then explored. Reference lists from these articles were also hand searched for relevant studies.

Insert table 1 here

2.2 Inclusion and exclusion criteria

Due to the nature of the review, only quantitative, peer-reviewed studies were included. This included studies published in English, from January 2003 onwards. The rationale for this date was that, to the authors knowledge, this was the first time

the benefits of assisted cycling were mentioned in the literature.[8] Results from the search were screened using the inclusion and exclusion criteria (Table 2).

Participants in both the intervention and control groups needed to have a formal diagnosis of PD and the intervention had to be a structured programme including an element of assisted cycling. Motor function had to be assessed prior to and after the trial, although the precise time frame was not stipulated.

Insert table 2 here

2.3 Quality assessment and data collection

A modified version of a checklist, developed by Downs and Black[22] was used to evaluate the quality of the studies identified from the database searches (Table 3). The checklist validates the reporting, external validity, internal validity and power of a study. The version used for this review substituted the statistical power question for a simplified, sample size justification question to accommodate for the information provided in the identified studies.

Insert table 3 here

Data was collected using a devised data extraction template. The template included section headings for the populations, interventions, comparisons and outcomes of the included studies.[23] This data extraction lead to the succinct summarisation of studies and subsequent identification of key themes.

3. Results

3.1 Included studies

The search strategy yielded a total of 71 studies, 64 did not meet the inclusion criteria or were duplicates in other database searches. A total of seven studies were

appropriate for review, including four randomised control trials (RCTs), one case control trial, one before-after pilot trial with cross-over and a single-subject design study. A PRISMA diagram[24] (Figure 1) shows how these were identified from the results of the search strategy.

Insert figure 1 here

3.2 Quality assessment

All the studies scored between 13 and 19 points on the quality assessment checklist, with three studies scoring ≥ 16 points (Table 3). The Ridgel *et al.*[25] and Mohammadi-Abdar *et al.*[26] RCTs scored highest with 19 points. Whereas, the preliminary study by Qutubuddin *et al.*[27] scored lowest with 13 points. Interestingly, the quality assessment scores closely reflect the hierarchy of evidence scale proposed by Evans,[28] with most RCTs scoring highest. No studies were excluded based on their quality.

3.3 Study characteristics

A comprehensive overview of the characteristics from the seven studies analysed is provided in Table 4.

Insert table 4 here

3.3.1 Sample population

Five of the studies[25,26,29-31] used the Hoehn and Yahr (H&Y) scale to screen participants' disease severity for inclusion. The H&Y scale's strengths include its simple and easy application,[32] contributing to its wide utilisation and acceptance.[33] The other two studies[27,34] used the motor component of the Unified Parkinson's Disease Rating Scale (UPDRS III), a clinical scale that evaluates tremor, bradykinesia, rigidity, posture and gait difficulties.[8]

Across the seven studies a total of 179 participants were included in both intervention and control groups, with sample sizes varying from 10[30,31,34] to 47.[25,26] Baseline H&Y scores varied from 1.6±0.5[29] to 2.13±0.16, [26] with UPDRS III scores ranging from 15.7±6.2[27] to 49.0±15.4.[34] Mean ages ranged from 61.2±6.0[34] to 68.2±8.8; [27] the majority of participants were male. More detailed population demographics can be found in Table 4.

All studies were conducted in the USA, with participants being recruited from community support groups in three of the studies, [29-31] and clinic recruitment in one study.[27] In the remaining studies the recruitment of participants was not described.[25,26,34] The participant demographics of Ridgel *et al.*[25] and Mohammadi-Abdar *et al.*[26] were similar, although no mention is given to the studies being linked.

3.3.2 Intervention and control measures

All the exercise and control interventions, included for review, were of different intensities and durations. Ridgel *et al.*[34] conducted their RCT over an eight-week period, with three one-hour sessions per week. Using a tandem-style exercise bike with an able-bodied trainer, participants were required to maintain a cadence that was 30% more than their voluntary rate. Another trial[27] was conducted over the same duration, and included two thirty-minute sessions per week on a stationary active assisted bicycle. Ridgel *et al.*[29] included a three-week programme, with one forty-minute session of passive cycling on a motorized cycle, randomised to a cadence of 60, 70 or 80rpm, per week. A before-after style trial by Ridgel *et al.*[30] used a single forty-minute session of active assisted cycling, maintaining a desired cadence of 80-85rpm. This involved the participant pushing on the pedals and doing work, however if they were unable to overpower the motor, the motor would take over and reduce the workload of the individual. Uygur *et al.*[31] used a single-subject study design where participants were exposed to four 30-minute interventions over a two-week period. Familiarisation sessions, no-pedalling sessions, preferred cadence sessions and high-speed with low-resistance (HS-LR) sessions were included. Another study[25] included a one-week programme of four forty-minute sessions where participants were encouraged to maintain a cadence of 75-85rpm and 50-80% of their maximum heart rate. Finally, Mohammadi-Abdar *et al.*[26] exposed participants

to a one-week exercise programme with three forty-minute sessions of dynamic cycling, using a smart exercise bike set to dynamic mode. Readers are directed to a design study by Mohammadi-Abdar *et al.*[7] for an in-depth description of the smart exercise bike and its variety of exercise modalities.

Three of the studies[25,26,34] used a bike setup where the control participants pedalled at a self-selected cadence, with no motor assist. Participants were instructed to maintain the same target heart rate as those in the corresponding intervention group. There were an equal number of control sessions, over the same duration as the intervention sessions. Usual care, with no special exercise intervention, was used as a control for two of the studies.[27,29] In the remaining studies[30,31] controls were not required due to the nature of the study designs.

3.3.3 Study outcomes

Four of the studies[25-27,34] used the UPDRS III as an outcome measure. Out of these studies, three[25,26,34] demonstrated statistically significant improvements immediately after the intervention. In addition, Ridgel *et al.*[34] measured UPDRS III four-weeks after testing and found an 11% improvement remained from pre-trial measurements, approaching statistical significance. The remaining study[27] showed no significant improvement at the end of testing, however there was a significant within-group improvement at four months in the experimental group, when compared to baseline UPDRS III measurements. Statistically significant improvements in quantitative tremor and bradykinesia outcomes, using Kinesia™ software, were observed by Ridgel *et al.*[29] Following on from this research, Ridgel *et al.*[30] found a similar trend of significant quantitative improvements in tremor and bradykinesia in a single session paradigm. Interestingly, Uygur *et al.*[31] used a plethora of functional outcomes. However, significant improvements were only observed in the 4-square step test and 10-metre walk test.

Overall, there is moderate evidence to suggest the efficacy of assisted cycling for improving motor function in those with PD. This was determined using a levels of evidence method suggested by van Tulder *et al.*[35]

4. Discussion

4.1 Methodological analysis

The completion of quality assessment checklists highlighted some differences in the types of outcome measures that were employed. For example, the use of software like Kinesia™ produced quantitative and illustratable results, whereas, the UPDRS III provided more subjective data from a clinician scored motor evaluation. Therefore, the heterogeneity of outcome measures affected the ability to compare the results of the different studies.

Quality assessment highlighted the staff and facilities of the studies were not representative of usual care. Apart from the Qutubuddin *et al.*[27] study, all the trials that described their setting, took place in laboratories.[25,26,29-31] Expensive physiological monitoring and exercise equipment was often used, potentially limiting the intervention's widespread application in a clinical setting. A more cost-effective apparatus was used in an earlier trial.[34] However, when describing this study, Ridgel *et al.*[29] highlights the limitations and impracticalities of using a tandem bicycle.

Post-intervention follow-up results were only obtained in two studies.[27,34] Follow-up results using the UPDRS III scores at four-weeks, show a short durational improvement in motor function,[34] with a requirement for longer testing times to understand the long-term efficacy of the intervention. Additionally, it seems quite unlikely that interventions of such short duration can lead to the long-term reversal of symptoms that take decades to develop. Interestingly, the significant within-group improvement in motor function, shown at four-months post-intervention by Qutubuddin *et al.*, [27] suggests the improvements following assisted cycling are delayed. This may have been the case if the other RCTs in this review had obtained follow-up results, however this study was of the lowest quality and only showed a within-group improvement, limiting extrapolation to other studies.

4.2 Baseline demographics

Results suggest that an exercise intervention of similar duration and intensity may have varied benefits depending on the stage of PD. Two studies investigated the effect of assisted cycling at 60-80% of participants' maximum heart rates, over an

eight-week period.[27,34] Ridgel *et al.*[34] found a significant improvement in UPDRS III scores immediately after testing in a group with more severe baseline PD. While, Qutubuddin *et al.*[27] failed to show any significant improvement, in a population with less severe baseline PD symptoms. A similar trend was mirrored between Ridgel *et al.*[25] and Uygur *et al.*[31] Although different study designs, with different durations, Ridgel *et al.*[25] found significant improvements in the timed-up-and-go (TUG) outcome. However, Uygur *et al.*[31] showed no significant improvements, in a participant group with slightly less advanced PD. Overall, these results provide evidence that baseline disease severity may contribute to the efficacy of an assisted cycling exercise intervention in improving motor function.

4.3 Exercise interventions – frequency, intensity, time and type

Comparison of all seven studies suggests the frequency of sessions and intervention duration influences outcomes. Ridgel *et al.*[25] produced significant improvements in UPDRS III over a one-week period. However, the original eight-week trial by Ridgel *et al.*[34] showed the greatest improvements. Therefore, results highlight an eight-week, trainer-assisted cycling programme to be the most effective intervention. Since this study was of the longest duration and had the greatest frequency of sessions, it is difficult to determine specifically which factors were most responsible for the observed improvements in motor function. Contrary to the aforementioned results, Ridgel *et al.*[30] showed significant improvements in tremor and bradykinesia outcomes after a single forty-minute session of assisted cycling. However, Qutubuddin *et al.*[27] failed to show any improvement after a total of eight-hours of sessions of similar intensity. As previously discussed, the baseline characteristics of participants may have affected these results. As different disease severity measures were employed, a comparison of baseline characteristics between the two studies is difficult to ascertain.[27,30] It is not possible to determine the optimal session frequency and intervention duration, for improving motor function from these studies.

The results suggest that certain intensities and types of assisted cycling are more beneficial than others. In a single-subject design trial by Uygur *et al.*[31] a significant improvement in functional outcomes was only found with a HS-LR intervention. Cycling at a preferred cadence failed to show any improvement.[31] Comparison of the two RCTs that showed greatest improvement in UPDRS III scores reinforces this

idea further because of the high intensities employed.[25,34] In isolation, it is difficult to determine specifically whether the increased cadence, heart rate or power output was responsible for the greater improvement in function by Ridgel *et al.*[34] The study[26] that documented exact cadence, power and heart rate values, states cadence values were higher in their successful intervention group. However, power and heart rate were higher in their control group. The results from this high-quality study are supportive of the fact that increased cadence may be responsible for greater improvements. The study by Qutubuddin *et al.*[27] was the only other study that may have provided a comparison as it used the UPDRS III as an outcome measure, however, this study failed to provide cadence data. Overall, results suggest an intervention with increased cadence is most effective in improving motor function, as opposed to an increased power output or heart rate. Yet, optimal, severity-specific cadences are still to be determined.

Interestingly, all the studies included in this review used an exercise intervention targeting lower limb cycling. However, most of the improvements shown were in upper extremity outcome measures. It is suggested that this provides evidence of holistic changes that involve the central nervous system. This may be because of an increase in afferent input to the cortex, contributing to global improvements in motor function.[8] Additionally, in numerous studies, bouts of exercise have been shown to create changes in neuroplasticity.[37-41] This may have occurred as a result of changes in neurotrophic factor levels.[42] Whilst the exact mechanisms responsible for the observed improvements is not fully known, the evidence provided in this review highlights the potential for assisted cycling as an intervention to improve global motor function.

4.4 Limitations

Only studies written in English were included in this review, thus selection bias is possible.[43] Outcome measures varied between studies, reducing the ability to simultaneously compare results from all studies. The small number of studies included for this review also minimise the generalisability of findings. Furthermore, the limited number of participants may affect the formation of reliable conclusions.

5. Conclusion

This review has established that there is moderate evidence that assisted cycling can effectively improve motor function in those with PD. In addition, it is suggested that an assisted cycling intervention is more beneficial to those with more advanced baseline PD. There was evidence of improvements in motor function in those with less advanced baseline PD, but these were smaller. The results of this review were not able to determine an optimum assisted cycling intervention in terms of the frequency, duration and length. It is suggested that interventions should focus on including a high-cadence exercise protocol, with less emphasis on power output and heart rate. Future research should employ larger sample populations with follow-up measurements at regular periods, to determine the long-term motor benefits. The exploration of different modes of exercise, that can achieve a similar intensity to that of the cycling interventions highlighted in this review, may also prove beneficial. Development of cost-effective equipment, that can be operated independently, will help to accelerate the implementation of assisted cycling into a government funded healthcare system, that can be implemented in clinical, leisure centre and home settings.

6. Disclaimer Statements

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Conflicts of interest: The authors have no conflict of interest to disclose.

Ethics approval: Informed consent was not required for this study as it was a review of published literature**.**

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Figure 1. PRISMA flow diagram of search strategy. The search strategy for the identification of seven publications from seven databases used in this review.

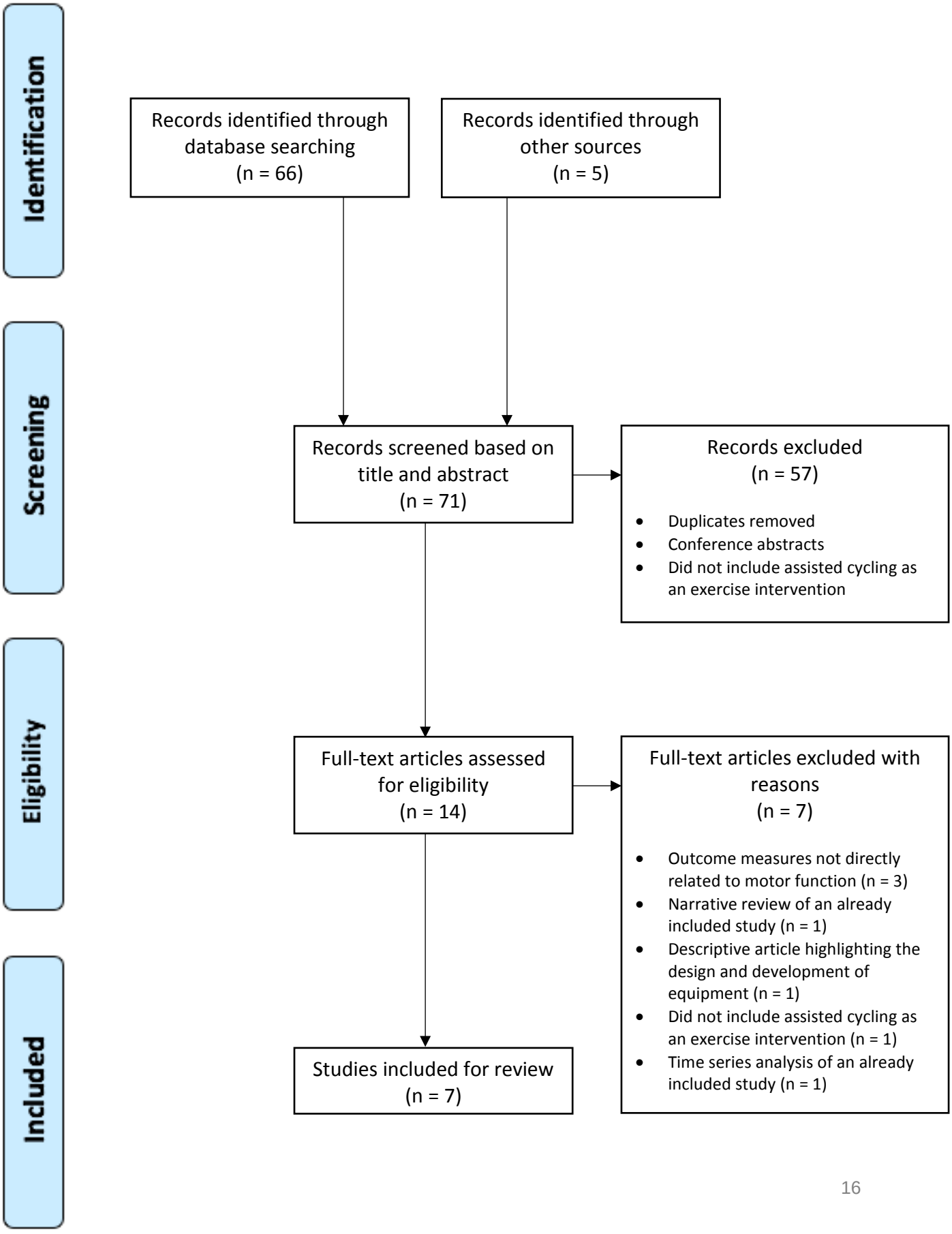

Table 1. Search terms applied and sample strategy

	Alternatives	Results
Term		
1) Parkinson's	Parkinson* PD	601,966
2) Cycling	Cycle Bicycle Bicycling Bike	15,857
3) Assisted	Active-assisted "Active assisted" Forced Dynamic Passive	1,418
4) Motor function	UPDRS "Unified Parkinson* Disease Rating Scale" Tremor Bradykinesia	66
Sample search strategy	1 (Parkinson* OR PD) 2 (Cycling OR Cycle OR Bicycle OR Bicycling OR Bike) 3 (Assisted or Active-assisted or "Active Assisted" OR Forced OR Dynamic OR Passive) 4 ("Motor Function" OR UPDRS OR "Unified Parkinson* Disease Rating Scale" OR Tremor OR Bradykinesia)	

* (asterisk) represents truncation

Table 2. Inclusion/exclusion criteria for the selection of articles

Inclusion	Exclusion
Population • Studies where the participants had a formal diagnosis of Parkinson's disease	Population • Studies where the participants did not have a formal diagnosis of Parkinson's disease
Intervention • Studies using an assisted cycling intervention, whereby a set cadence was greater than a voluntary rate	Intervention • Studies using forced exercise, without an element of cycling
Outcome • Studies using outcome measures relating to motor function, either quantitative or functional • Studies with a baseline measures as well as retesting of measures	Outcome • Studies using non-functional outcome measures, for example: fMRI results
Other • Studies published in peer-reviewed journals	Other • Reports published in conferences

- Reviews or analyses of already included studies

Table 3. Modified Downs and Black (1998) checklist

	Ridgel et al. (2009)	Ridgel et al. (2011)	Ridgel et al. (2012)	Qutubuddin et al. (2013)	Ridgel et al. (2015)	Uygur et al. (2015)	Mohammadi-Abdar et al. (2016)
Q1 – Is the hypothesis/aim/objective clearly described?	1	1	1	1	1	1	1
Q2 – Are the main outcomes to be measured clearly described?	1	1	1	1	1	1	1
Q3 – Are the characteristics of the patients included in the study clearly described?	1	1	1	0	1	0	1
Q4 – Are the interventions of interest clearly described?	1	0	1	1	1	1	1
Q5 – Are the distributions of principal confounders in each group of subjects to be compared clearly described?	1	1	0	0	1	0	1
Q6 – Are the main findings of the study clearly described?	1	1	1	1	1	1	1
Q7 – Does the study provide estimates of the random variability in the data for the main outcomes?	1	1	1	1	1	1	1
Q8 – Have all the important adverse events that may be a consequence of the intervention been reported?	0	0	1	0	0	0	0
Q9 – Have the characteristics of patients lost to follow-up been described?	1	1	1	1	1	1	1
Q10 – Have actual probability values been reported for the main outcomes?	1	1	1	1	1	1	1
Q11 – Were the subjects asked to participate in the study representative of the	0	0	0	0	0	0	0

entire population from which they were recruited?							
Q12 – Were those subjects who were prepared to participate representative of the entire population from which they were recruited?	0	0	0	0	0	0	0
Q13 – Were the staff, places, and facilities where the patients were treated representative of the treatment the majority of patients receive?	0	0	0	1	0	0	0
Q14 – Was an attempt made to blind study subjects to the intervention they have received?	0	0	0	0	0	0	0
Q15 – Was an attempt made to blind those measuring the main outcomes of the intervention?	1	0	0	0	1	0	1

Table 4. Data extraction table for the seven included studies

Study	Aims	Design	Population	Intervention/Control	Outcome	Quality Assessment
Ridgel et al. (2009) Forced, Not Voluntary, Exercise Improves Motor Function in Parkinson's Disease Patients	To compare the effects of voluntary exercise and forced exercise on Parkinson's disease symptoms, motor function and bilateral dexterity	Randomised Control Trial	<u>Sample selection:</u> Not described <u>Age:</u> 61.2±6.0 <u>Size:</u> n = 10 - Intervention group n = 5, Control group n = 5 <u>Disease severity:</u> Intervention group UPDRS III = 48.4±12.7, Control group UPDRS III =	<u>Intervention Group</u> 8-week: 3 x 1-hour exercise sessions per week 10-minute warm-up, 40-minute exercise set (80-90rpm or 30% more than voluntary rate) (60%-80% of MHR) assisted by an able-bodied trainer on a tandem-style exercise bike, 10-minute cool-down <u>Control Group</u>	<u>Intervention Group</u> UPDRS III EOT – 35% significant improvement (48.4-31.8) UPDRS III EOT + 4/52 – 11% improvement (Rigidity EOT – 41% significant improvement Tremor EOT – 38% significant improvement Bradykinesia EOT – 28% significant improvement) <u>Control Group</u> UPDRS III EOT	18 (66.7%) Modified Downs and Black

			49.0±15.4 <u>Sex (M/F):</u> 8/2	8-week: 3 x 1-hour exercise sessions per week 10-minute warm-up, 40-minute exercise set (60%-80% of MHR), 10-minute cool-down	– no improvement (49.0-52.6) UPDRS III EOT + 4/52 – no improvement	
Ridgel et al. (2011) Acute Effects of Passive Leg Cycling on Upper Extremity Tremor and Bradykinesia in Parkinson's Disease	To determine whether passive leg cycling can promote immediate changes in upper tremor and bradykinesia in Parkinson's disease and if pedalling rates have variable effects	Case Control Trial	<u>Sample selection:</u> Community support groups and local neurology clinics. No mention of randomisation <u>Age:</u> Intervention group = 62.8±8.5, Control group = 64.6±5.8 <u>Size:</u> n = 32 - Intervention group n = 20, Control group n = 12 <u>Disease severity:</u> Intervention group H&Y 2.0±0.8, Control group H&Y 1.6±0.5 <u>Sex (M/F):</u> 22/10	<u>Intervention Group</u> 3-week: 1 x 40-minute session per week 5-minute warm-up (40rpm), 30-minute exercise set (leg rotation speed randomised to 60, 70 or 80rpm on a motorized cycle), 5-minute cool-down (40rpm) <u>Control Group</u> Single session of assessment before and after watching a short instructional video about the MOTOmed motorized cycle	<u>Intervention Group</u> Tremor: Kinesia Tremor Score – 0.25 improvement (pre-test 2.6±2.5) Bradykinesia: Hand Grasp (Item 24 of UPDRS III) – 0.10Hz improvement (pre-test 1.7±0.4Hz) Pronation/supination (Item 25 of UPDRS III) – 0.18Hz improvement (pre-test 1.3±0.4Hz) <u>Control Group</u> Tremor: Kinesia Tremor Score – 0.28 worsening (pre-test 3.0±2.2) Bradykinesia: Hand Grasp (Item 24 of UPDRS III) – 0.15Hz worsening (pre-test 1.6±0.7Hz) Pronation/supination (Item 25 of UPDRS III) – 0.19Hz worsening (pre-test 1.3±0.5Hz)	15 (55.6%) Modified Downs and Black

Ridgel et al. (2012) Active-Assisted Cycling Improves Tremor and Bradykinesia in Parkinson's Disease	To investigate a high-speed active-assisted paradigm using a commercially available motorized cycle trainer and examine physiological perimeters during these sessions in individuals with Parkinson's disease	Before-after Pilot Trial with Cross-over	Sample selection: Community support groups Age: 64±2.1 Size: n = 10 Disease severity: H&Y 1.8±0.3 Sex (M/F): 4/6	A single-active-assisted cycling exercise session while off anti-Parkinson's medications. 5-minute warm-up (40-50rpm), 30-minute main set (75rpm, patient asked to pedal at 80-85rpm), 5-minute cool-down (40-50rpm) Measurements taken ON Pre-AAC, OFF Pre-AAC and OFF Post-AAC	Tremor: ON Pre-AAC (2.47±0.80) OFF Pre-AAC (3.25±0.91) OFF Post-AAC (2.40±0.81) 78% of participants showed improvements from OFF Pre-AAC to OFF Post-AAC OFF Post-AAC tremor scores were similar to ON Pre-ACC scores Bradykinesia: Worsening in movement speed from ON Pre-AAC to OFF Pre-AAC (p = <0.001) Improvement in movement speed from OFF Pre-AAC to OFF Post-AAC (p = <0.001) No significant difference between ON Pre-AAC and OFF Post-AAC (p = 0.303)	15 (55.6%) Modified Downs and Black
Qutubuddin et al. (2013) Parkinson's Disease and Forced Exercise: A Preliminary Study	To ascertain any significant effect of forced exercise using a motorized stationary bicycle when compared to controls on Parkinson's disease symptoms	Randomised Control Trial	Sample selection: Hospital and clinic advertisements Age: 68.2±8.8 Size: n = 23 - Intervention group n = 13, Control group n = 10 Disease severity: Intervention	Intervention Group 8-week: 2 x 30-minute exercise sessions per week Warm-up, 30-minute exercise set (61%-80% of MHR), cool-down Control Group Usual clinic care, involving medical visits and appropriate medication changes as	Intervention Group UPDRS III EOT – no significant improvement (15.7±6.2 – 14.2±8.4) UPDRS III EOT + 4/12 – significant improvement (15.7±6.2 – 10.4±4.8) Control Group UPDRS III EOT – no significant improvement (16.9±6.5 –	13 (48.1%) Modified Downs and Black

			group UPDRS III = 15.7±6.2, Control group UPDRS III = 16.9±6.5 <u>Sex (M/F):</u> Not described	necessary. No specialised physical therapy or exercise conditioning	15±6.8) UPDRS III EOT + 4/12 – no significant improvement (16.9±6.5 – 14.1±7.1) No significant differences in BBS score, finger tap and PDQ-39 for both groups	
Ridgel et al. (2015) Dynamic High-Cadence Cycling Improves Motor Symptoms in Parkinson's Disease	To examine if high cadence dynamic cycling promotes improvements in motor function	Randomised Control Trial	<u>Sample selection:</u> Not described <u>Age:</u> Intervention group = 67.2±1.6, Control group = 67.3±0.9 <u>Size:</u> n = 47 - Intervention group n = 24, Control group n = 23 <u>Disease severity:</u> Intervention group H&Y 2.1±0.2, Control group H&Y 1.8±0.1 <u>Sex (M/F):</u> 29/18	<u>Intervention Group</u> 1-week: 4 x 40-minute sessions 5-minute warm-up (40-50rpm), 30-miniute main set (75-85rpm, motor did majority of work, but participants encouraged to push on pedals and not to be passive) (50-80% of MHR), 5-minute cool-down (40-50rpm) <u>Control Group</u> 1-week: 4 x 40-minute sessions 5-minute warm-up (40-50rpm), 30-miniute main set (Self-selected speed without motor assist) (50-80% of MHR), 5-minute cool-down (40-50rpm)	<u>Intervention Group</u> UPDRS III – 13.9% significant improvement (p = 0.013) Timed-up-and-go (TUG) – 16.5% significant improvement (p = 0.10) <u>Control Group</u> UPDRS III – 0.9% non-significant improvement (p = 0.85) Timed-up-and-go (TUG) – 8% non-significant improvement (p = 0.19)	19 (70.4%) Modified Downs and Black

Uygur et al. (2015) Immediate Effects of High-Speed Cycling Intervals on Bradykinesia in Parkinson's Disease	To test the immediate effects of high-speed cycling intervals on bradykinesia in people with Parkinson's disease	Single-subject Design	<u>Sample selection:</u> Community support groups <u>Age:</u> 64.6±5.5 <u>Size:</u> n = 10 <u>Disease severity:</u> H&Y 1.95±0.73 <u>Sex (M/F):</u> 9/1	Four laboratory visits within a 2-week period. For PC and HS-LR cycle resistance set on the lowest level at which subjects produced less than 100 Watts of power at their fastest FPC <u>1st Session</u> Familiarisation session, introduction to equipment and testing <u>NO Session</u> Time control session, subjects sat on recumbent cycle for 30 minutes <u>PC Session</u> Subjects instructed to pedal for 30 minutes at a comfortable pace <u>HS-LR Session</u> 5-minute warm-up, 20-minute main set (increase cadence to a self-selected FPC for the first 15 seconds of every minute), 5-minute cool-down	<u>HS-LR Session</u> 4SST – significant improvement (7.70±2.13s – 7.13±2.02s) 10mW – significant improvement (3.51±1.18s – 3.38±1.16s) No significant improvements in other outcomes for all exercise sessions: TUG, 9HPT, time required to button a shirt, area of subject's signature, area of standard set of three word, SRT, CRT, IPT and isometric grip strength	15 (55.6%) Modified Downs and Black

Mohammadi-Abdar et al. (2016) Test and Validation of a Smart Exercise Bike for Motor Rehabilitation in Individuals with Parkinson's Disease	To assess and validate the Smart Exercise Bike designed for Parkinson's Disease rehabilitation and to investigate the impact of cycling on changes in motor skills	Randomised Control Trial	<u>Sample selection:</u> Not described <u>Age:</u> Intervention group = 67.17±1.66, Control group = 67.26±0.97 <u>Size:</u> n = 47 - Intervention group n = 24, Control group n = 23 <u>Disease severity:</u> Intervention group H&Y 2.13±0.16, Control group H&Y 1.83±0.14 <u>Sex (M/F):</u> 28/19	<u>Intervention Group</u> 1-week: 3 x 40-minute sessions Dynamic mode: operating at a user defined cadence set point with programmable load fluctuations that introduce cadence variations <u>Control Group</u> 1-week: 3 x 40-minute sessions Static mode: operates as a regular exercise bike, a pre-set torque with the participant varying the cadence	<u>Intervention Group</u> UPDRS III – 13.85% significant improvement (30.4 – 26.2) <u>Control Group</u> UPDRS III – 1.6% worsening (25.2 – 25.6)	19 (70.4%) Modified Downs and Black

AAC – Active assisted cycling
CRT – Choice reaction time
EOT – End of testing
FPC – Fast pedalling cadence
HS-LR – high-speed with low-resistance
H&Y – Hoehn and Yahr
IPT – Information processing time
MHR – Maximum heart rate
NO – No pedalling
PC – Preferred cadence
RPM – Revolutions per minute
SRT – simple reaction time
TUG – Timed-up-and-go
UPDRS III – Unified Parkinson's Disease Rating Scale (Motor component)
4SST – 4-square step test
9HPT – 9-hole peg test
10mW – 10m walk test