The Effects of Exercise on Balance in Persons with Parkinson's Disease: A Systematic Review Across the Disability Spectrum

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Background and Purpose: Parkinson's disease is a progressive neurodegenerative disorder that affects neurophysiologic function, movement abilities, and quality of life (QOL). Research examining the effects of exercise has suggested benefits related to a variety of outcomes; however, no reviews have synthesized research findings across the spectrum of disability. This project sought to systematically review studies that examined the impact of exercise interventions on balance outcomes for people with Parkinson's disease, within the categories defined by the World Health Organization in the International Classification of Functioning, Disability, and Health (ICF) model.

Methods: A systematic review of medical literature databases was performed using keywords Parkinson's disease and exercise. Studies were eligible if the intervention included exercise and examined variables within one of the three ICF categories. Following the ICF model, outcomes regarding Body Structure and Function, Activity, and Participation were measured, respectively, in terms of postural instability, balance task performance, and QOL and fall events.

Results: Within the Body Structure and Function category, there was moderate evidence that exercise resulted in improvements in postural instability. Within the Activity category, there was moderate evidence that exercise was effective for improving balance task performance. In contrast, within the Participation category, there was limited evidence that exercise resulted in improvements in QOL measures or fall events.

Discussion and Conclusions: Regardless of the strength of the evidence, the studies reviewed all report that exercise resulted in improvements in postural stability and balance task performance. Despite these improvements, the number and quality of the studies and the outcomes used were limited. There is a need for longer term follow-up to establish trajectory of change and to determine if any gains are retained long term. The optimal delivery and content of exercise interventions (dosing, component exercises) at different stages of the disease are not clear.

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INTRODUCTION

Epidemiologic estimates suggest that idiopathic Parkinson's disease (PD) currently affects between 4.1 and 4.6 million individuals older than the age of 50 years in the world's 10 most populous nations.[1] PD commonly presents with progressive postural instability, hypokinesia, rigidity, and tremor.[2,3] In part, the motor manifestations of PD result from selective neuronal loss in the motor circuits of the basal ganglia.[4] The development of Lewy neurites and Lewy bodies within poorly myelinated neurons of the midbrain leads to loss of dopaminergic neurons and a resultant neurotransmitter imbalance.[4] Although PD sporadically occurs and is variable in its presentation, the effects of PD on neurologic function consistently contribute to increasing disability over time.

A number of systematic and narrative reviews have been undertaken to investigate the efficacy of rehabilitation among people with PD.[5–11] Most of these reviews categorize the effects of interventions on specific constructs, such as disease severity (as measured by the Unified Parkinson's Disease Rating Scale and Hoehn and Yahr stages) or specific tasks (such as gait and measured by gait speed). Application of the International Classification of Functioning, Disability, and Health (ICF) model of the World Health Organization (WHO) to PD would allow the integration of several perspectives regarding the spectrum of disability associated with PD.[12–14] To our knowledge, no reviews have used the ICF model as a basis to specifically evaluate interventions of physical activity and exercise on balance-related outcomes.

The PD movement deficit of postural instability is particularly problematic for rehabilitation clinicians in that it contributes to an increased frequency of falls and fall-related injuries relative to neurologically healthy individuals.[15,16] To further compound the problem, as a movement deficit, postural instability may be resistant to improvement with dopamine replacement medications.[17–19] Studies of fall incidence in persons with PD suggest that over the course of the disease, the majority of individuals with PD will develop problems with postural instability and falls.[16,20] In addition, there are consistent reports of postural instability being a strong determinant of perceived disability in PD and that

postural instability and falls lead to an increase in morbidity and mortality.[20–23] Considered together, this makes balance-related outcomes particularly relevant to rehabilitation providers. In an effort to make this systematic review applicable to problems faced in clinical practice, we used the ICF model as the basis for systematic review of research studies regarding the effects of physical activity and exercise on the consequences of PD-related postural instability across the continuum of disability (Figure 1).

Previous narrative and systematic reviews focused on the effects of rehabilitation or physical therapy on persons with PD.[5–11] In our preliminary literature searches for this review, we found that such a constraint limited the literature reviewed by excluding exercise or other manipulations of the amount of physical activity not classified as either rehabilitation or physical therapy. To ensure as comprehensive a review of the literature as possible, the interventions of interest were operationally defined as physical activity and exercise, and we used search parameters targeted at any interventions that manipulated the amount of physical activity and exercise performed by persons with PD.

In the context of the ICF model, the WHO defines Body Structures as the anatomical parts of the body, such as organs, limbs, and their components, whereas Body Functions are defined as the physiologic functions of body systems.[12] In the health condition of PD, the PD movement deficit of postural instability represents a deficit in body function. For the purpose of this review variables used to characterize postural instability were instrumented measures targeted at physiologic measurement of balance control and included postural sway, stability in altered sensory environments, and biomechanical responses to internally and externally generated perturbations.[17–19] In the ICF, the WHO defines Activity as the execution of a task or action by an individual and Activity limitations as the difficulties an individual may have in executing activities. For the purposes of this review, the outcomes of interest reflected balance task performance during posturally challenging activities from everyday life. Measures used to characterize difficulties in balance task performance include clinical balance tests, such as the Berg Balance Scale, the Functional Reach Test, the Timed Up and Go Test, and the Tinetti Balance Assessment Tool. In the ICF model, the WHO defines Participation as the involvement in a life situation and Participation restrictions as problems an individual may experience in involvement in life situations. For the purposes of this review, measures used to characterize Participation restrictions include quality of life (QOL) measures and the frequency of fall events in everyday life situations.[12–14]

This systematic review seeks to provide clinicians with an in-depth examination of the evidence that may be used to justify physical activity and exercise as a means to improve postural instability, alter balance task performance, and influence QOL and fall events.[8,9,24] In a healthcare environment that more regularly demands knowledge of current evidence to support interventions, this systematic review is intended assist clinicians in gaining a better perspective of where along the ICF model clinical interventions may have an impact.

METHODS

Search Methodology

Our goal was to capture studies in international medical journals, published in the English language from 1995 to May 2008, that examined physical activity-related intervention studies targeted at the treatment of idiopathic PD. The following electronic databases were searched: MEDLINE (1995 to May 2008), Cumulative Index to Nursing and Allied Health

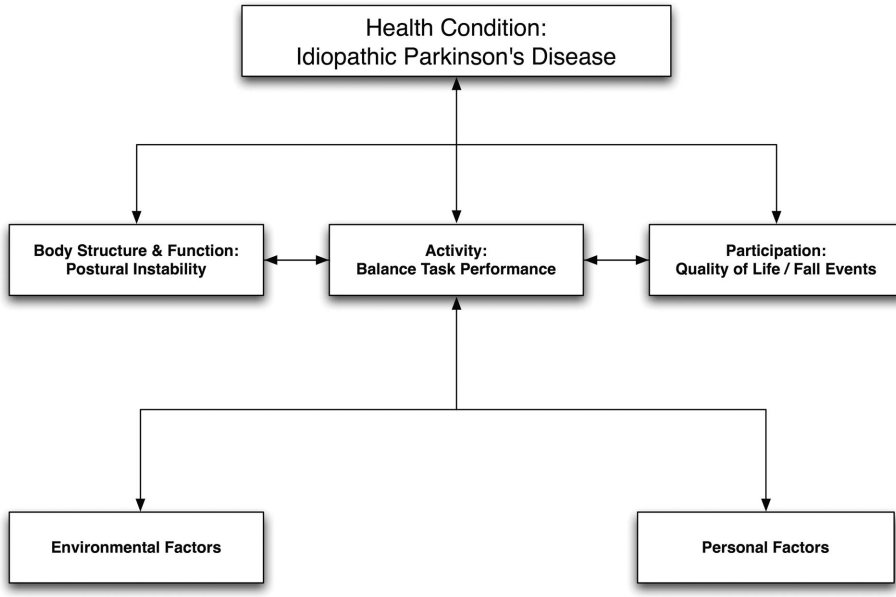

FIGURE 1. Categorization of balance outcomes using the World Health Organization's International Classification of Functioning, Disability, and Health model and the health condition of idiopathic Parkinson's disease.

Literature (1995 to May 2008), SPORTDiscus (1995 to May 2008), the Cochrane Library (1995 to May 2008), and Google Scholar (1995 to May 2008). In addition, literature was identified by citation tracking using reference lists from included studies.

For each search, we first specified the population of interest by identifying descriptors related to the health condition of idiopathic PD. This was then followed by limiting the findings of the health condition search with descriptors related to the intervention (physical activity and exercise). Next, this refined search was further limited by descriptors of the specific outcomes of interest (postural instability, balance task performance, and QOL). Last, we constrained the search with the limits of English language only, design type, and publication date (since 1995). In parallel, each of the three researchers undertook the initial literature search. Once we arrived at the citation list that resulted from the above-described search parameters, all three researchers reviewed abstracts and titles to identify eligible studies. Studies explicitly evaluating the immediate effects of sensory cueing strategies or the immediate effect of interventions such as whole body vibration were not included as we were interested in the clinical benefit of physical activity and exercise as opposed to acute immediate responses to any therapeutic tool. If it was unclear whether the study was relevant to this review, advice was sought from the other researchers and inclusion or exclusion decisions were made. Based on consensus decisions from the three researchers, a list of final citations was generated and the full text of these articles was procured for full article review. Figure 2 illustrates the process of the search strategy and provides detail regarding the number of full articles reviewed and those included in the final analysis.

Full Article Review: Level of Evidence, Quality Assessment, and Data Extraction

Two authors (O.A., E.P.), using standardized methods, independently extracted the data from each article selected for full review. The level of evidence/quality assessment/data extraction forms included the key general study information (title, author, and year of publication), study characteristics (population data, intervention, control or comparison, and outcomes), and results, including length of follow-up. A level

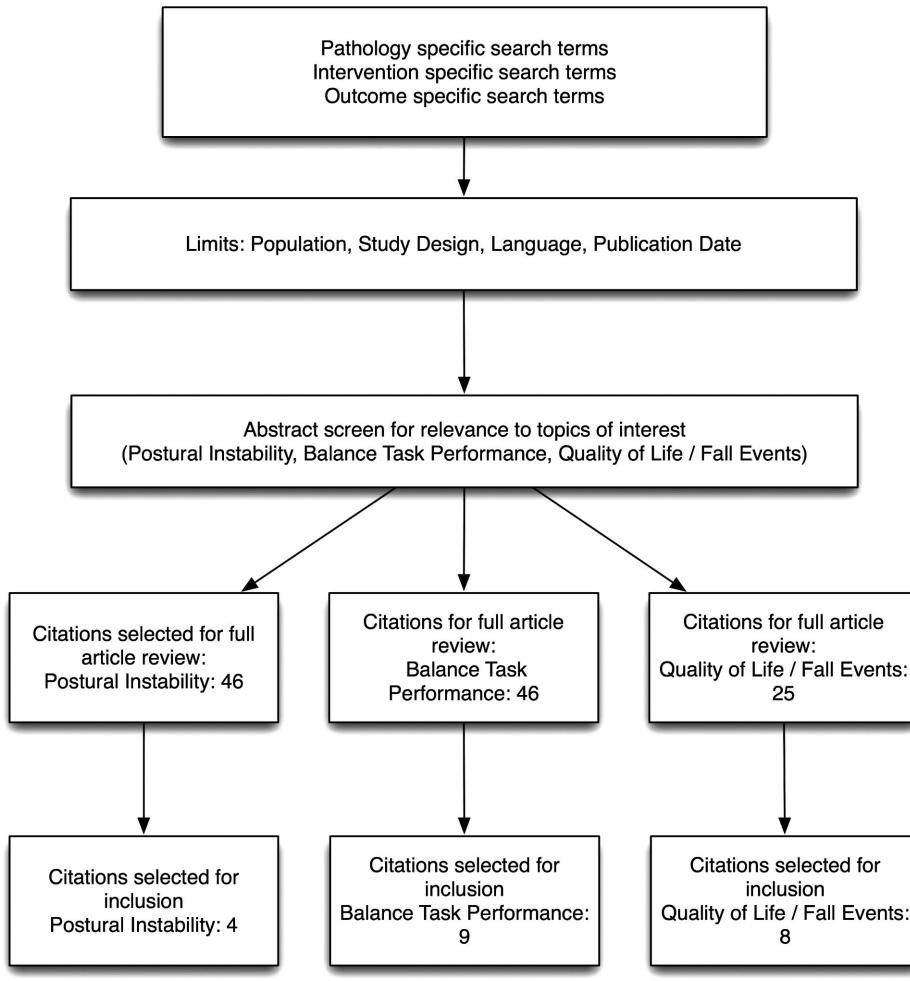

FIGURE 2. Search strategy and sequence. Note the stepwise progression leading to full article reviews and selection of citations selected for inclusion.[10,20,22,25–45]

of evidence rating and the numerical quality score for each study was calculated using a scale described by the American Academy of Cerebral Palsy and Developmental Medicine (AACPDM).[46] This tool rates the level of evidence on a five-category scale (level I = systematic review, level 5 = expert opinion case study) (see Appendix A for components of the AACPDM criteria). In addition, it assesses quality by awarding one point for each of the following internal and external validity study characteristics: (1) well-defined inclusion and exclusion criteria, (2) intervention adequately described and adherence to intervention, (3) measures used were valid and reliable, (4) outcome assessor was blinded, (5) authors conducted tests of and reported statistical power, (6) dropouts were reported and were less than 20%, and (7) appropriate methods for controlling confounding variables were used. A score of 3 or less was considered to be low quality, a score of 4 or 5 was considered to be moderate quality, and a score of 6 or greater was considered to reflect a high-quality trial. Any discrepancies in data extraction or quality assessment were resolved by reference to the original article and discussion between the researchers. If there were questions and it was possible, the original investigators were asked for additional data or clarification of methods. If the first two authors reached no consensus, a third reviewer (L.E.D.) made the final judgment.

A study was included if it met the following criteria: (1) a controlled clinical trial methodology was used (meeting definitions for levels I, II, and III evidence according to AACPDM criteria); (2) quality rating of more than 3 by AACPDM criteria; (3) the target population were individuals with idiopathic PD; (4) the effects of physical activity or exercise interventions were compared with control or comparison groups, including other forms of physical activity and exercise; (5) the outcomes included at least one of the following: postural instability, deficits in balance demanding activities, or health-related QOL; and (6) the article was available in English. A study was excluded if (1) the acute effects of a nonexercise/physical activity intervention were evaluated (examples include behavioral interventions, external sensory cuing, and whole body vibration); (2) a descriptive, cross-sectional, or single-subject design was used; (3) the level of evidence was 4 or 5 or quality rating was 3 or less as determined by the AACPDM criteria (Appendix A).

Data Analysis and Synthesis

Kappa (κ) statistics for interrater agreement were calculated for the level of evidence and quality ratings. To synthesize the results within each category of the ICF model, we used the best evidence synthesis method summarized in Appendix B.

RESULTS

The κ coefficients of the level of evidence and quality ratings were consistently high (>0.93) and reflected a high degree of agreement between the raters. The presentation of the methodologic details of specific articles was widely variable with few studies rated high quality, that is, a score of 6 or 7 on the AACPDM rating scale. In the Body Structure and Function category, 46 studies that examined postural instability outcomes were identified, only four met the inclusion criteria and were included in our analyses.[47–50] Only one of the four included studies was classified as a high-quality study with explicit statements regarding stringent controls for threats to internal validity.[49] In the Activity category, 46 studies that examined balance task performance were identified, only nine met our inclusion criteria and were included in our analyses.[25,47,49–55] Three of the nine included studies were classified as high quality.[49,54,55] Of the 25 studies identified from our search that examined Participation-related outcomes (PD-specific QOL and falls in a nonclinical environment), eight met our inclusion criteria and were included in our analyses.[10,25,28,32,39,43,45,54] Three of the eight included studies that were classified as high-quality studies[28,32,54] (Figure 2). Most commonly, research reports in all categories failed to cite power/sample size calculations, the reliability and validity of the outcomes used, the use of intention to treat analyses, and whether evaluators were blinded (Table 1). Last, none of the studies reviewed reported on the magnitude of change on individual outcome measures relative to a minimal detectable change (MDC) or a minimum clinically important difference (MCID).

TABLE 1. Level of Evidence and Methodological Quality Ratings

ICF Category and Citation	Level of Evidence	Quality Rating
Body Structure and Function (Postural Instability)		
Ebersbach et al[47]	II	4
Hirsch et al[48]	II	5
Tamir et al[49]	III	6
Toole et al[50]	III	4
Activity (Balance Test Performance)		
Asburn et al[26]	II	5
Caglar et al[51]	III	5
Cakit et al[52]	II	4
Ebersbach et al[47]	II	4
Hackney et al[53]	II	5
Protas et al[54]	III	6
Schenkman et al[55]	II	6
Tamir et al[49]	III	6
Toole et al[50]	III	4
Participation (Quality of Life/Fall events)		
Asburn et al[26]	II	5
Burini et al[29]	II	6
Ellis et al[33]	II	7
Keus et al[10]	II	5
Pacchetti et al[40]	II	4
Protas et al[54]	III	6
Schmitz-Hubsch et al[44]	II	4
Wade et al[46]	II	5

Sixteen studies were reviewed overall. Five studies used outcomes in more than one ICF category.

Abbreviation: ICF, International Classification of Functioning, Disability, and Health.

Interventions

Across all studies, 11 of 16 studies (69%) reported that physical therapists delivered the exercise interventions.[10,25,28,32,39,45,47–49,54,55] In 14 of the 16 studies (88%), interventions were provided in an outpatient care setting.[10,28,32,39,43,45,47–50,52–55] All the studies reassessed outcomes immediately post-intervention; however, only seven of the 16 performed follow-up again at a later date (range of follow-up: two weeks to one year) to observe for any lasting benefit or any detraining effect.[25,32,39,43,47,48,50] In 15 of the 16 studies, it was explicitly evident that some means of balance training was provided. Across all the studies, the interventions were heterogeneous with regard to the type, intensity, frequency, and duration of exercise provided.

Body Function: Postural Instability

The sample size for each study ranged from 15 to 23.[48,49] For those studies that reported the sex of participants, 55% were male. The Hoehn and Yahr Scale of PD severity was used in all the studies. The range of disease severity of participants was 1.8 to 2.3.[26,48]

Interventions ranged from whole-body vibration and imagery to traditional physical therapy and balance training. Ebersbach et al[47] was included because the authors studied the effects of a three-week program that used exercise interventions in both the experimental and control groups in addition to using whole-body vibration in the experimental group. Intervention intensity, frequency, and duration were highly variable, ranging from three to 12 weeks, two to 10 times per week for a total intervention time of 6 to 24 hours (Table 2).

Of the four studies that examined postural stability measures, three used laboratory measures to evaluate postural instability[47,48,50] (Sensory Organization Test [SOT], falls latency during the SOT, percentage of falls during the SOT, and computerized posturography). Two of these studies[48,50] found significant between-group improvements during post-testing in posturography variables, whereas only one noted significant between-group differences in falls during testing.[50] Two studies used the posterior Pull Test as described in the Unified Parkinson's Disease Rating Scale, but no statistically significant improvement was found in this measure.[47,49]

All reviewed studies used active control groups, and three of the four studies[48–50] demonstrated measurable improvements in the variables of interest in these groups. Because of the inclusion of active control groups, no data were available regarding the natural history of postural instability in the case of no intervention.

Activity: Balance Task Performance

The range of sample size for each study was 18 to 142.[25,54] For those studies that reported the sex of participants, 62% were male. The Hoehn and Yahr Scale of PD severity was used in six studies.[47,49–51,54,55] The range of disease severity of participants was 2.2 to 2.9.[18,26]

Interventions ranged from whole-body vibration and progressive tango training to more traditional forms of exercise, such as body weight support treadmill training and lower extremity strengthening. Intervention intensity, frequency, and duration were highly variable, ranging from three to 12 weeks, two to 10 times per week for a total intervention time of six to 20 hours (Table 3).

Nine studies reported on balance task performance using a variety of tools. All nine studies examined clinical measures of balance (Functional Reach Test, Tinetti Balance Assessment Tool, Dynamic Gait Index, Berg Balance Scale, Timed Up and Go Test, and time to turn around a chair).[25,47,49–55] Statistically significant improvements in balance task performance, as found in at least one clinical balance measure, were reported in all nine studies. Ebersbach et al[47] did not find any significant interaction effect for the Tinneti Balance Assessment Tool, but did report a significant time effect. Likewise, Toole et al[50] did not find a significant interaction effect for the Berg Balance Scale, but did report a significant time effect. Both of these studies used varied amounts of physical activity as interventions in both the experimental and comparison groups. Five of the nine studies reviewed used physically inactive control groups.[25,51,52,54,55] In those studies, three of five reported worsening of performance in the control groups.[25,51,52]

Participation: QOL

The range of sample size for each study was 18 to 142.[25,54] For those studies that reported the sex of participants, 67% were male. The Hoehn and Yahr Scale of PD severity was used in four of eight studies.[10,28,32,54] The range of disease severity of participants was one to four, with the majority of studies examining participants at Hoehn and Yahr stages 2 to 3.

Interventions ranged from Qigong and music therapy to more traditional forms of exercise, such as resistance training, aerobic exercise, range of motion/stretching, and treadmill training. Seven of the eight reviewed studies explicitly reported on the inclusion of postural control tasks in their intervention. In the study by Wade et al,[45] the inclusion was inferred based on the detail provided. Intervention intensity, frequency, and duration were highly variable ranging from six to 13 weeks, one to seven times per week for a total intervention time of 9.2 to 42 hours (Table 4).

Seven studies reported QOL outcomes using a variety of tools (Euro Quol EQ-5D, Parkinson's Disease Questionnaire, Parkinson's Disease Quality of Life Scale, Medical Outcomes Scale Short Form-36, and Sickness Impact Profile).[10,25,28,32,39,43,45] Of the seven studies, only two reported improvements in QOL. Ellis et al[32] reported statistically significant improvements in the Sickness Impact Profile mobility subsection, whereas Keus et al[10] did not report any statistically significant improvements in QOL but did report a clinically relevant improvement in mobility-related QOL. Wade et al[45] reported statistically significant declines in QOL as measured by the Medical Outcomes Scale Short Form-36 and Euro Quol EQ-5D measures across all participants. Only two of the nine studies examined the number of near-falls and falls before and after the intervention.[25,54] Ashburn et al[25] used a fall diary for this purpose and found a significant decrease in near-falls at eight weeks and six months post-exercise intervention, and they also saw a trend that did not

TABLE 2. Summary of Citation Included for Body Function, ICF Category: Postural Instability

Reference (Total N)	Exp/ Control (n)	Severity H&Y UPDRS	Mean Age	Duration of PD	Type of Intervention for Exp (wks/freq/min/total hrs)	Type of Intervention for Control (wks/freq/min/total hrs)	Measure/Results
Ebersbach et al[47] (27)	Exp = 14 (M = 7, F = 3) Control = 13 (M = 7, F = 4)	H&Y E = 2.3 (0.7) C = 2.2 (0.6) UPDRS Motor E = 23.0 (4.9) C = 25.9 (8.1)	Exp = 72.5 (6.0) Control = 75.0 (6.8)	Exp = 7.0 (3.3) Control = 7.5 (2.7)	Whole Body Vibration, speech therapy, occupational therapy, relaxation 3/10/15/7.5 (for vibration)	Tilt board balance, speech therapy occupational therapy, relaxation 3/10/15/7.5 hr (for tilt board)	Posturography (mm): Exp Start/End/fu: 1937.0 (1250)/ 1306.0 (331.0)/1467.0 (540) Control Start/End/fu: 1832.0 (746.0)/2256.0 (681.0)/ 2030.0 (878) Shoulder tug (1 best to 5 worst): Exp Start/End/fu: 1.45 (0.68)/1.17 (0.72)/1.05 (0.64) Control Start/End/fu: 1.7 (0.79)/1.32 (0.40)/1.27 (0.47)
Hirsch et al[48] (15)	Exp = 6 Control = 9 numbers of men and women not reported	H&Y E = 1.8 (0.3) C = 1.9 (6)	Exp = 70.8 (2.8) Control = 75.7 (1.8)	Exp = 5.5 (3.91) Control = 8.3 (9.8)	Balance exercise and strength training for ankle plantarflexors and knee extensors and flexors 10/3/45/22.5	Balance 10/3/30/15	Sensory organization test: Exp Start/End: 59.0 (8.5)/75.1 (3.1)[a] Control Start/End: 52.8 (8.2)/60.1 (3.4) Latency to fall: Exp Start/End: 16.5 (1.8)/18.8 (0.6)[a] Control Start/End: 15.5 (1.5)/18.0 (0.7)[a] % trial resulting in falls: Exp Start/End: 28.2 (12.0)/7.9 (0.4)[a] Control Start/End: 36.0 (11.1)/16.0 (6.1)[a]
Tamir et al[49] (23)	Exp = 12 (M = 8, F = 4) Control = 11 (M = 7, F = 4)	H&Y E = 2.29 (0.4) C = 2.31 (0.4) UPDRS Motor E = 23.2 C = 26.0	Exp = 67.4 (9.7) Control = 67.4 (9.1)	Exp = 7.4 (3.1) Control = 7.8 (4.5)	PT plus imagery 12/2/60/24	Callisthenic, practice specific functions, relaxation 12/2/60/24	Shoulder tug: Exp Start/End: data not provided, 40% improvement Control Start/End: data not provided 20% improvement
Toole et al[50](23)	Total (M = 19, F = 4) Exp unweighted = not reported Exp weighted = not reported Control = not reported	Disease severity not specified using standard Hoehn and Yahr scoring[b]	Exp unweighted = 76.42 (10.24) Exp weighted = 72.0 (11.47) Control = 75.37 (7.99)	Not reported	Treadmill no weight Treadmill plus weight 6/3/20/6	Treadmill 6/3/20/6	Neurosensory organization test: Group main effect F = 4.27, P = 0.03, ES = 0.38 unloaded group > TM alone. Falls during SOT TM alone and unloaded group had < falls after intervention (Kruskal-Wallis = 9.154, P = 0.01) TM > number of falls than unloaded group

[a] Statistically significant differences.
[b] Toole et al report calculation for Hoehn and Yahr not consistent with previously reported literature.
Abbreviations: H&Y, Hoehn and Yahr; UPDRS, Unified Parkinson's Disease Rating Scale; M, males; F, females; Exp, experimental group; fu, follow-up; PT, physical therapy.

TABLE 3. Summary of Citations Included for Activity, ICF Category: Balance Task Performance

Reference (Total N)	Exp/Control (n)	Severity H&Y UPDRS	Mean Age	Duration of PD	Type of Intervention for Exp (wks/freq/min/total hr)	Type of Intervention for control (wks/freq/min/total hr)	Measure/Results
Ashburn et al[26] (142)	Exp = 70 (M = 38, F = 32) Control = 72 (M = 48, F = 24)	UPDRS E = 19.8 (8.3) C = 22.2 (11.9)	Exp = 72.7 (9.6) Control = 71.6 (8.8)	Exp = 7.7 (5/8) Control = 9.0 (5.8)	Muscle Strengthening, Range of motion, Balance training, walking 6/7/60/42	Visit with PD nurse	Functional Reach test (cm): Exp Start/8 wk/6 mo: 23.2/23.6/23.8[a] Control start/8 wk/6 mo: 25.0/24.0/22.5 Berg Balance Test (out of 56): Exp start/8 wk/6 mo: 44.3/45.8/45.3 Control start/8 wk/6 mo: 43.6/45.2/44.6
Caglar et al[51] (30)	Exp = 15 (M = 11, F = 4) Control = 15 (M = 10, F = 5)	H&Y #E Stage 1/2/3: 2/10/3 #C 1/2/3: 1/11/3	Exp = 67.4 (5.0) Control = 64.3 (12.3)	Exp = 5.2 (2.7) Control = 5.5 (2.7)	Home based exercise 8/7/?/?	No intervention	Time to turn around chair: Exp baseline/1 mo/2 mo 8.5/7.0[a]/5.5[a] Control baseline/1 mo/2 mo 10.3/12.2/12.6
Cakit et al[52] (54)	Exp = 21 Control = 10 (M = 16, F = 15)	UPDRS-MS All participants 18.14 (9.32)	All participants 1.8 (6.4)	All participants 5.58 (2.9)	Incremental speed-dependant treadmill training 8/?/30/?	No intervention	Berg Balance Test (out of 56): Exp = baseline/8 wk[a] 37.0/44.1 Control = baseline/8 wk: 42.6/41.4 Dynamic Gait Index (out of 24): Exp = baseline/8 wk[a]: 11.8/16.5 Control = baseline/8 wk: 16.3/16.0
Ebersbach et al[47] (27)	Exp = 14 (M = 7, F = 3) Control = 13 (M = 7, F = 4)	H&Y Exp = 2.3 (0.7) Control = 2.2 (0.6) UPDRS-MS Exp = 23.0 (4.9) Control = 25.9 (8.1)	Exp = 72.5 (6.0) Control = 75.0 (6.8)	Exp = 7.0 (3.3) Control = 7.5 (2.7)	Whole Body Vibration, speech therapy, occupational therapy, relaxation 3/10/15/7.5 (for vibration)	Tilt board balance, speech therapy, occupational therapy, relaxation 3/10/15/7.5 hr (for tilt board)	Tinetti Balance Scale Score: Exp Start/End/fu: 9.3 (3.1)/12.8 (1.9)/12.8 (2.3) Control Start/End/fu: 8.3 (2.9)/11.5 (2.4)/11.7 (3.1)
Hackney et al[53] (19)	Exp = 9 (M = 6, F = 3) Control = 10 (M = 6, F = 4)	UPDRS-MS Exp = 30.6 (1.3) Control = 28.2 (1.2)	Exp = 72.6 (2.2) Control = 69.6 (2.1)	Exp = 6.2 (1.5) Control = 3.3 (0.5)	Progressive Tango dance lessons 10/2/60/20	Strength/flexibility group exercise 10/2/60/20	Berg Balance Scale (out of 56): Main effect of time F = 8.6 $P = 0.01$ Exp Start/End: 46.8 (1.0)/50.6 (1.0)[a] ES = 0.90 Control Start/End: 45.4 (0.9)/47.1 (0.9) ES = 0.27 Timed Up and Go (sec) Exp Start/End:11.7 (0.4)/9.8 (0.4) ES = 0.37 Control Start/End: 11.7 (0.4)/11.8 (0.4) ES = 0.02

TABLE 3. Summary of Citations Included for Activity, ICF Category: Balance Task Performance. (continued)

Reference (Total N)	Exp/Control (n)	Severity H&Y UPDRS	Mean Age	Duration of PD	Type of Intervention for Exp (wks/freq/min/total hr)	Type of Intervention for control (wks/freq/min/total hr)	Measure/Results
Protas et al[54] (18)	Exp = 9 (M = 9, F = 0) Control = 9 (M = 9, F = 0)	H&Y Exp = 2.8 (0.35) Control = 2.9 (1.7) UPDRS-MS Exp = 28.3 (13.6) Control = 30.4 (8.0)	Exp = 71.3 (7.4) Control = 73.7 (8.5)	Exp = 7.1 (5.1) Control = 8.1 (4.4)	Body weight support treadmill training, forward, fastest, backwards, sidestep, step training 8/3/?/24 sessions	No intervention	Step test (steps/sec): Exp Start/End: 0.4 (0.08)/ .51 (0.12)[a] Control Start/End:.36 (0.11)/ .42 (0.11)[a]
Schenkman et al[55] (delayed start design) (46)	Group 1 = 23 (M = 18, F = 5) Group 2 = 23 (M = 16, F = 7)	H&Y Group 1 Stage2/2.5/3: 7/6/10 Group 2 Stage2/2.5/3: 3/6/14	Group 1 = 70.6 (6.2) Group 2 = 71.2 (7.3)	Not reported	Flexibility training targeted at the axial skeleton. Individualized graduated functional training (10/3/?/?)	No intervention	Functional Reach Change score (in) Group 1 = 0.62 (1.75) Group 2 = 0.73 (1.68) All subjects after intervention = 0.7 (0.2)[a] Turning 360 degrees change score (sec) Group 1 = −0.37 (1.4) Group 2 = −1.36 (3.5) All subjects after intervention = −0.8 (0.4)[a]
Tamir et al[49] (23)	Exp = 12 (M = 8, F = 4) Control = 11 (M = 7, F = 4)	H&Y E = 2.29 (0.4) C = 2.31 (0.4) UPDRS Motor E = 23.2 C = 26.0	Exp = 67.4 (9.7) Control = 67.4 (9.1)	Exp = 7.4 (3.1) Control = 7.8 (4.5)	PT plus imagery 12/2/60/24	Callisthenic, practice specific functions, relaxation 12/2/60/24	Timed up and go (sec) Exp Start/End: $t = 3.80$, $P = 0.0005$[a] Control Start/End: Not reported Functional reach (cm) Exp Start/End: $t = -1.92$, $P = 0.06$ Control Start/End: $t = -1.82$, $P = 0.08$
Toole et al[50] (23)	Total (M = 19, F = 4) Exp unweighted = not reported Exp weighted = not reported Control = not reported	Disease severity not specified using standard Hoehn and Yahr scoring[b]	Exp unweighted = 76.42 (10.24) Exp weighted = 72.0 (11.47) Control = 75.37 (7.99)	Not reported	Treadmill no weight Treadmill plus weight 6/3/20/6	Treadmill 6/3/20/6	Berg Balance test Main effect for Time $F = 12.37$, $P = 0.0001$, ES = 0.41 Post-test & fu > pretest

[a] Statistically significant differences.
[b] Toole et al report calculation for Hoehn and Yahr not consistent with previously reported literature.
? = Specifics regarding dosage not reported.
Abbreviations: H&Y, Hoehn and Yahr, UPDRS, Unified Parkinson's Disease Rating Scale, M, males, F, females, Exp, experimental group, fu, follow-up, PT, physical therapy, ES, effect size.

TABLE 4. Summary of Citations Included for Participation, ICF Category: QOL/Fall Events

Reference (Total N)	Exp/Control (n)	Severity H&Y UPDRS	Mean Age (SD) years	Duration of PD (SD) years	Type of Intervention for Exp (wks/freq/min/total hr)	Type of Intervention for Control (wks/freq/min/total hr)	Measure/Results
Ashburn et al[26] (142)	Exp = 70 (M = 38, F = 32) Control = 72 (M = 48, F = 24)	UPDRS Exp = 19.8 (8.3) Control = 22.2 (11.9)	Exp = 72.7 (9.6) Control = 71.6 (8.8)	Exp = 7.7 (5/8) Control = 9.0 (5.8)	Muscle strengthening, range of motion, Balance training, walking 6/7/60/42	Visit with PD nurse	Euro Qol EQ-5D (0–100) Exp baseline/8 wk/6 mo 63.1/61.3/63.0 Control base line/8 wk/6 mo 64.6/61.7/56.6 Diary of falls: Exp 8 wk/6 mo: 37/46 Control 8 wk/6 mo: 42/49 Near falling: Exp 8 wk/6 mo: 46/50 Control 8 wk/6 mo: 55/57
Burini et al[29] (cross over design) (26)	Group 1 = 13 (M = 5, F = 8) Group 2 = 13 (M = 4, F = 9)	H&Y Group 1 Stage 2/3: 3/10 Group 2 Stage 2/3: 4/9	Group 1 = 65.7 (7) Group 2 = 62.7 (4)	Group 1 = 11.2 (5.4) Group 2 = 10.6 (4.8)	Qigong 7/3/50/17.5	Aerobic exercise 7/3/45/15.75	PDQ-39 (0–100): Group 1 baseline/T1/T2/T3 25/41/41/39 Group 2 baseline/T1/T2/T3 45/53/40/42
Ellis et al[33] (cross over design) (68)	Group 1 = 35 Group 2 = 33 (M = 51, F = 17)	H&Y 2.4 (0.5)	Group 1 = 64 (8.4) Group 2 = 63 (8.8)	Not reported	PT (strength training, gait training, balance training, treadmill training) + Medical Therapy 6/2/90/18	Medical therapy only	Sickness Impact Profile-mobility: Group 1 baseline/6 wk/12 wk 46.1/−1.5[a]/−0.8[a] Group 2 baseline/6 wk/12 wk 45/.2/.3
Keus et al[10] (27)	Exp = 14 (M = 11, F = 3) Control = 13 (M = 11, F = 2)	H&Y (number in Exp/Control) 1 (2/2) 2 (6/5) 3 (5/5) 4 (1/1)	Exp = 65.4 Control = 70.5	Exp = 7 Control = 6	Meds + PT 9/1.55/42 to 60/9.2	Medical therapy only	PDQ-39 mobility subsection (0–100) Mean change Exp improved by 4.11 Control worsened −2.12
Pacchetti et al[39] (32)	Exp = 16 (M = 12, F = 4) Control = 16 (M = 11, F = 5)	UPDRS-MS Exp = 40.2 Control = 40.7	Exp = 62.5 (5) Control = 63.2 (5)	Exp = 4.8 (3) Control = 5.2 (2)	Music therapy 13/1/120/26	PT 13/1/90/19.5	PDQ-39[b] Exp baseline/wk 7/wk 11 (114/127/132) Control baseline/wk 7/wk 11 (125/115/117)
Protas et al[54] (18)	Exp = 9 (M = 9, F = 0) Control = 9 (M = 9, F = 0)	H&Y Exp = 2.8 (0.35) Control = 2.9 (1.7) UPDRS-MS Exp = 28.3 (13.6) Control = 30.4 (8.0)	Exp = 71.3 (7.4) Control = 73.7 (8.5)	Exp = 7.1 (5.1) Control = 8.1 (4.4)	Body weight support treadmill training, forward, fastest, backwards, sidestep, step training 8/3/?/24 sessions	No intervention	Fall frequency Exp Start/End: 5 had falls/2 had falls Control Start/End: 6 had falls/4 had falls
Schmitz-Hubsch et al[44] (56)	Exp = 32 (M = 24, F = 8) Control = 24 (M = 19, F = 5)	UPDRS-MS Exp = 15.5 Control = 16.9	Exp = 64 (8) Control = 63 (8)	Exp = 6.0 (5.5) Control = 5.6 (3.8)	Qigong 8/8/1/90/24	No intervention	PDQ-39 (0–100) No between group differences

TABLE 4. Summary of Citations Included for Participation, ICF Category: QOL/Fall Events. (continued)

Reference (Total N)	Exp/Control (n)	Severity H&Y UPDRS	Mean Age (SD) years	Duration of PD (SD) years	Type of Intervention for Exp (wks/freq/min/total hr)	Type of Intervention for Control (wks/freq/min/total hr)	Measure/Results
Wade et al[46] (94)	Exp = 53 (M = 30, F = 23) Control = 41 (M = 26, F = 15)	PDQ-39 Exp = 26.1 Control = 27.6	Exp = 71.3 (8.6) Control = 70.4 (7.6)	Not reported	Early multidisciplinary 6/1/day/42	Late multidisciplinary 6/1/day/42	Results from baseline to 24 wk on all participants PDQ-39 (0–100): no change SF-36 (0–100):[a] worsened 50.3/38.7[a] Euroqol (0–100) worsened 0.72/0.66[a]

[a] Statistically significant differences; EuroQOL EQ-5D, Parkinson's Disease Questionnaire (PDQ-39), and Medical Outcomes Scale Short Form-36, higher scores = better QOL rating; Sickness Impact Profile mobility (somatic autonomy, mobility control, mobility range) higher scores = poorer health-related QOL rating.

[b] Pachetti et al report ranges of values for the PDQ-39 not calculated in the manner described by the authors of the PDQ-39. Their report of higher scores indicating improvement is in contrast to the referenced scoring of the PDQ-39.

Abbreviations: H&Y, Hoehn and Yahr, UPDRS, Unified Parkinson's Disease Rating Scale, M, males, F, females, Exp, experimental group, fu, follow-up, PT, physical therapy, QOL, Quality of life.

reach statistical significance in the number of total falls post-intervention. Protas et al[54] also noted a trend that did not reach statistical significance in fall frequency post-intervention. Five of the eight studies reviewed used physically inactive control groups.[10,25,32,43,54] There was no consistent pattern of improvement or worsening among these studies.

DISCUSSION

This systematic review was intended to provide a summary of current evidence and assist clinicians in gaining a better perspective on where clinical interventions for balance problems may have an impact along the ICF model. The results of our review determined that in the Body Structure and Function ICF category, there is moderate evidence that physical activity and exercise will result in improvements in postural instability outcomes in persons with mild to moderate PD[47,48,50] (Appendix B, Table 2). In balance task performance (ICF Activity category), there is moderate evidence present to support physical activity and exercise as an effective intervention to improve balance task performance in persons with mild to moderate PD[25,49,51–54] (Appendix B, Table 3). There is limited evidence to support an improvement in QOL outcomes (ICF Participation category) with physical activity and exercise interventions in persons with mild to moderate PD.[32] In addition, there are only indicative findings that such interventions can affect near-falls and falls[25,54] (Appendix B, Table 4). Such findings complement the conclusions of other recent systematic reviews regarding the effectiveness of rehabilitation or physical therapy on these outcomes.[5–11] Currently, questions remain, given the current body of evidence, as to the appropriate type and amount of physical activity and exercise to impart benefits on postural instability, balance task performance, and QOL/fall event outcomes.

Support for the Acute Benefits of Increased Activity

The studies reviewed for the ICF Activity (balance task performance) and Participation (QOL/fall events) categories were comparable in that most of the studies assessed outcomes at three time points to track any detraining effects that may have occurred after the intervention period was complete. The studies reviewed consistently demonstrated acute benefits from the interventions studied with this being, particularly evident from those studies that used crossover designs. However, the follow-up examinations varied from two weeks to 12 months. No studies examined outcomes beyond 12 months post-intervention, and only one study examined outcomes at 12 months. Therefore, it is not possible to determine whether any of the interventions exerted a lasting effect on the progression of disability in the subjects studied.

It is interesting to note that in balance task performance, most of the studies failed to find an interaction effect, but demonstrated a time effect.[25,48–54] These studies usually used some form of physical activity or exercise in their control group. Although the interventions used were heterogeneous, generally the physical activity and exercise amount was greater in the experimental groups. This suggests that

although an increased amount of exercise may amplify any observed benefits, some form of physical activity or exercise (regardless of group assignment) may be beneficial for balance task performance in persons with mild to moderate PD. It also suggests that the relative impact of physical activity and exercise may be underestimated. Many of the reviewed studies used multidimensional training programs rather than directly address postural instability in their interventions. The lack of task-specific training is likely due to our limited understanding of the critical underlying mechanisms contributing to postural instability in PD. Advances in this area may lead to more targeted, successful interventions.

Are Appropriate Outcome Measures Being Used in PD Research?

Regardless of the strength of the evidence, the studies reviewed all report that physical activity and exercise resulted in some measurable improvement in postural instability and balance task performance measures.[25,49–54] Despite consistent improvements in postural instability measures, the number and quality of the studies and the outcomes used were limited. Based on this synthesis, one potential question raised is whether appropriate outcome measures are being used. Although biomechanical measures of sway or clinical balance tests may be the easiest measures to gather, they represent only one potential contributor to potential falls in persons with PD. As components of the ICF model, environmental and personal factors represent two potential contributors to falls that were not examined or part of the interventions provided by the included studies (Figure 1). Although many of the characteristics of PD postural instability have been described using kinematic, kinetic, and electromyographic measures during reactive and anticipatory postural tasks,[18,56–59] such outcomes and tasks were absent in the intervention studies reviewed. For these reasons, insight into the mechanisms of the changes was not available.

The studies reviewed provided limited evidence that physical activity and exercise may improve self-reported QOL in persons with PD. When reported, the primary effect of the interventions was on the mobility subsections. Although most of the measures used have subscales that reflect movement and body comfort–related constructs (eg, mobility and bodily discomfort subscales in the Parkinson's Disease Questionnaire), details about the differential effects of the interventions on these subsections was not consistently provided.[25,28,39,43,45] Such practices may obscure a differential effect on the body movement–related subscales or may ignore additional effects (beneficial or detrimental) on other subscales. Regardless, more detail regarding the effects of physical activity and exercise effects on QOL is present in these studies and has not been consistently reported.

Only two studies examined falls or near-falls as outcomes.[25,54] The combined sample of these studies represents a relatively limited number of participants and occurred in two different care settings (home based and outpatient).[25,54] In both studies, participant self-report was used to determine the number of fall or near-fall events. Although the optimal means of fall monitoring is unknown, participant self-report may not provide accurate estimates, especially in a sample of persons with PD who may have impaired cognition.[60]

Although most of the studies reviewed report statistically significant differences in the outcomes studied, none report the magnitude of these changes relative to MDC or MCID.[61] Determination of the MDC for the outcome measures would provide greater clarity regarding whether intervention-induced changes exceeded the inherent variability of the outcome measures used. Rather than relying on statistical change, inclusion of MCID values would provide a more participant-centered approach to the determination of clinical relevance.[61]

Limitations

There are several limitations to this review. First, we limited our search strategy and subsequent review to evidence ranked as level I, II, or III, as designated by AACPDM, in articles that were published in English-language, peer-reviewed publications. By design, this may disregard potentially clinically relevant findings. Second, we framed this systematic review using the ICF model to categorize outcome measures. This organization is a strength in that it separates particular aspects of postural control into distinct categories that may facilitate clinicians' ability to understand the impact of exercise on the various aspects of postural control. However, it is also a weakness given the complex nature of postural control, with contributions from multiple motor and sensory systems. Although we categorized outcomes based on ICF definitions, the potential for artificial segregation and overlap of constructs exists. In addition, this review implies a relationship between the components of the ICF model. Only five of the reviewed studies include measures of postural control across multiple ICF categories and none concurrently examined postural control outcomes in all three categories. Therefore, the relationship between postural instability, balance task performance, and QOL/fall events remains unclear. Last, our choice to examine specific categories of outcomes within ICF categories caused us to extract the variables of interest from the context of individual studies. Such a process constrained our ability to comment on the overall merits of any individual study that we reviewed.

Implications and Directions for Future Research

To our knowledge, this is the first systematic review to examine the effects of physical activity and exercise on balance outcomes across the spectrum of the ICF model. Although there is moderate evidence that physical activity and exercise will result in improvements in postural instability and balance task performance measures in persons with mild to moderate to severe PD, the evidence that these interventions meaningfully affect participation-related constructs is limited. A compelling finding of this review was that in those studies using an active control group, improvements in postural instability measures were observed, whereas most of those studies that used an inactive control group demonstrated a decline in balance task performance measures.[25,47,49–54] Considered together, these results imply that the type of activity may not be important, but rather that

the performance of some sort of physical activity or exercise as opposed to being sedentary is critical.

In the future, studies should include more participants at moderate stages of the disease (Hoehn and Yahr stages 3 and 4) and greater numbers of female participants. As technology allows, these trials should include specific biomechanical measures, such as those used in descriptive studies of PD postural instability.[18,56–59] Efforts should be made to examine specific component parts of measures of participation and examine the use of more sensitive and reliable monitoring of fall or near-fall events in the community. Such outcome measures should be used in conjunction with the examination of physical activity and exercise programs with explicitly defined content of the interventions (dosing, component exercises). There is a critical need for longer term studies (more than one year) to establish a trajectory of change in outcomes in experimental and control group participants and determine whether gains or lack of decline observed during intervention stages are retained over a broader time interval.

REFERENCES

1. Dorsey ER, Constantinescu R, Thompson JP, et al. Projected number of people with Parkinson's disease in the most populous nations, 2005 through 2030. *Neurology.* 2007;68:384–386.
2. Marjama-Lyons JM, Koller WC. Parkinson's disease. Update in diagnosis and symptom management. *Geriatrics.* 2001;56:24–25, 29–30, 33–25.
3. Wood B, Walker R. Parkinson's disease: characteristics of fallers and non-fallers. *Age Ageing.* 2001;30:423–424.
4. Braak H, Del Tredici K. Invited article: Nervous system pathology in sporadic Parkinson's disease. *Neurology.* 2008;70:1916–1925.
5. Crizzle AM, Newhouse IJ. Is physical exercise beneficial for persons with Parkinson's disease? *Clin J Sport Med.* 2006;16:422–425.
6. Horstink M, Tolosa E, Bonuccelli U, et al. Review of the therapeutic management of Parkinson's disease. Report of a joint task force of the European Federation of Neurological Societies (EFNS) and the Movement Disorder Society-European Section (MDS-ES). Part II: late (complicated) Parkinson's disease. *Eur J Neurol.* 2006;13:1186–1202.
7. Horstink M, Tolosa E, Bonuccelli U, et al. Review of the therapeutic management of Parkinson's disease. Report of a joint task force of the European Federation of Neurological Societies and the Movement Disorder Society-European Section. Part I: early (uncomplicated) Parkinson's disease. *Eur J Neurol.* 2006;13:1170–1185.
8. Jobges EM, Spittler-Schneiders H, Renner CI, et al. Clinical relevance of rehabilitation programs for patients with idiopathic Parkinson syndrome. II. Symptom-specific therapeutic approaches. *Parkinsonism Relat Disord.* 2007;13:203–213.
9. Jobges M, Spittler-Schneiders H, Renner CI, et al. Clinical relevance of rehabilitation programs for Parkinson's disease. I. Non-symptom-specific therapeutic approaches. *Parkinsonism Relat Disord.* 2007;13:195–202.
10. Keus SH, Bloem BR, van Hilten JJ, et al. Effectiveness of physiotherapy in Parkinson's disease: the feasibility of a randomised controlled trial. *Parkinsonism Relat Disord.* 2007;13:115–121.
11. Trend P, Kaye J, Gage H, et al. Short-term effectiveness of intensive multidisciplinary rehabilitation for people with Parkinson's disease and their carers. *Clin Rehab.* 2002;16:717–725.
12. World Health Organization. *International Classification of Functioning, Disability and Health: ICF*. Geneva, Switzerland: World Health Organization; 2001.
13. Coffin-Zadai CA. Disabling our diagnostic dilemmas. *Phys Ther.* 2007; 87:641–653.
14. Jette AM. Toward a common language for function, disability, and health. *Phys Ther.* 2006;86:726–734.
15. Ashburn A, Stack E, Pickering RM, et al. Predicting fallers in a community-based sample of people with Parkinson's disease. *Gerontology.* 2001;47:277–281.
16. Ashburn A, Stack E, Pickering RM, et al. A community-dwelling sample of people with Parkinson's disease: characteristics of fallers and non-fallers. *Age Ageing.* 2001;30:47–52.
17. Bloem BR, Beckley DJ, van Dijk JG, et al. Influence of dopaminergic medication on automatic postural responses and balance impairment in Parkinson's disease. *Mov Disord.* 1996;11:509–521.
18. Frank JS, Horak FB, Nutt J. Centrally initiated postural adjustments in parkinsonian patients on and off levodopa. *J Neurophysiol.* 2000;84: 2440–2448.
19. Horak FB, Frank J, Nutt J. Effects of dopamine on postural control in parkinsonian subjects: scaling, set, and tone. *J Neurophysiol.* 1996;75: 2380–2396.
20. Murray AM, Bennett DA, Mendes de Leon CF, et al. A longitudinal study of parkinsonism and disability in a community population of older people. *J Gerontol A Biol Sci Med Sci.* 2004;59:864–870.
21. Grisso JA, Kelsey JL, Strom BL, et al. Risk factors for falls as a cause of hip fracture in women. The Northeast Hip Fracture Study Group. *N Engl J Med.* 1991;324:1326–1331.
22. Quittenbaum BH, Grahn B. Quality of life and pain in Parkinson's disease: a controlled cross-sectional study. *Parkinsonism Relat Disord.* 2004;10:129–136.
23. Williams DR, Watt HC, Lees AJ. Predictors of falls and fractures in bradykinetic rigid syndromes: a retrospective study. *J Neurol Neurosurg Psychiatry.* 2006;77:468–473.
24. Goodwin VA, Richards SH, Taylor RS, et al. The effectiveness of exercise interventions for people with Parkinson's disease: a systematic review and meta-analysis. *Mov Disord.* 2008;23:631–640.
25. Ashburn A, Fazakarley L, Ballinger C, et al. A randomised controlled trial of a home based exercise programme to reduce the risk of falling among people with Parkinson's disease. *J Neurol Neurosurg Psychiatry.* 2007;78:678–684.
26. Baatile J, Langbein WE, Weaver F, et al. Effect of exercise on perceived quality of life of individuals with Parkinson's disease. *J Rehabil Res Dev.* 2000;37:529–534.
27. Brichetto G, Pelosin E, Marchese R, et al. Evaluation of physical therapy in parkinsonian patients with freezing of gait: a pilot study. *Clin Rehabil.* 2006;20:31–35.
28. Burini D, Farabollini B, Iacucci S, et al. A randomised controlled cross-over trial of aerobic training versus Qigong in advanced Parkinson's disease. *Eura Medicophys.* 2006;42:231–238.
29. Craig LH, Svircev A, Haber M, et al. Controlled pilot study of the effects of neuromuscular therapy in patients with Parkinson's disease. *Mov Disord.* 2006;21:2127–2133.
30. Cubo E, Bernard B, Leurgans S, et al. Cognitive and motor function in patients with Parkinson's disease with and without depression. *Clin Neuropharmacol.* 2000;23:331–334.
31. Dam M, Tonin P, Casson S, et al. Effects of conventional and sensory-enhanced physiotherapy on disability of Parkinson's disease patients. *Adv Neurol.* 1996;69:551–555.
32. Ellis T, de Goede CJ, Feldman RG, et al. Efficacy of a physical therapy program in patients with Parkinson's disease: a randomized controlled trial. *Arch Phys Med Rehabil.* 2005;86:626–632.
33. Inzelberg R, Peleg N, Nisipeanu P, et al. Inspiratory muscle training and the perception of dyspnea in Parkinson's disease. *Can J Neurol Sci.* 2005;32:213–217.
34. Jobges M, Heuschkel G, Pretzel C, et al. Repetitive training of compensatory steps: a therapeutic approach for postural instability in Parkinson's disease. *J Neurol Neurosurg Psychiatry.* 2004;75:1682–1687.
35. Klein PJ, Rivers L. Taiji for individuals with Parkinson's disease and their support partners: program evaluation. *J Neurol Phys Ther.* 2006; 30:22–27.
36. Maitra KK, Dasgupta AK. Incoordination of a sequential motor task in Parkinson's disease. *Occup Ther Int.* 2005;12:218–233.
37. Marras C, Lang A, Krahn M, et al. Quality of life in early Parkinson's disease: impact of dyskinesias and motor fluctuations. *Mov Disord.*2004; 19:22–28.
38. Pacchetti C, Aglieri R, Mancini F, et al. Active music therapy and Parkinson's disease: methods. *Funct Neurol.* 1998;13:57–67.
39. Pacchetti C, Mancini F, Aglieri R, et al. Active music therapy in

Parkinson's disease: an integrative method for motor and emotional rehabilitation. *Psychosom Med.* 2000;62:386–393.
40. Pellecchia MT, Grasso A, Biancardi LG, et al. Physical therapy in Parkinson's disease: an open long-term rehabilitation trial. *J Neurol.* 2004;251:595–598.
41. Reuter I, Harder S, Engelhardt M, et al. The effect of exercise on pharmacokinetics and pharmacodynamics of levodopa. *Mov Disord.* 2000;15:862–868.
42. Rodrigues de Paula F, Teixeira-Salmela LF, Coelho de Morais Faria CD, et al. Impact of an exercise program on physical, emotional, and social aspects of quality of life of individuals with Parkinson's disease. *Mov Disord.* 2006;21:1073–1077.
43. Schmitz-Hubsch T, Pyfer D, Kielwein K, et al. Qigong exercise for the symptoms of Parkinson's disease: a randomized, controlled pilot study. *Mov Disord.* 2006;21:543–548.
44. Stallibrass C, Sissons P, Chalmers C. Randomized controlled trial of the Alexander technique for idiopathic Parkinson's disease. *Clin Rehabil.* 2002;16:695–708.
45. Wade DT, Gage H, Owen C, et al. Multidisciplinary rehabilitation for people with Parkinson's disease: a randomised controlled study. *J Neurol Neurosurg Psychiatry.* 2003;74:158–162.
46. AACPDM methodology to develop systematic reviews of treatment interventions. Available at: http://www.aacpdm.org/resources/systematicReviewsMethodology.pdf, 2008.
47. Ebersbach G, Edler D, Kaufhold O, et al. Whole body vibration versus conventional physiotherapy to improve balance and gait in Parkinson's disease. *Arch Phys Med Rehabil.* 2008;89:399–403.
48. Hirsch MA, Toole T, Maitland CG, et al. The effects of balance training and high-intensity resistance training on persons with idiopathic Parkinson's disease. *Arch Phys Med Rehabil.* 2003;84:1109–1117.
49. Tamir R, Dickstein R, Huberman M. Integration of motor imagery and physical practice in group treatment applied to subjects with Parkinson's disease. *Neurorehabil Neural Repair.* 2007;21:68–75.
50. Toole T, Maitland CG, Warren E, et al. The effects of loading and unloading treadmill walking on balance, gait, fall risk, and daily function in Parkinsonism. *NeuroRehabilitation.* 2005;20:307–322.
51. Caglar AT, Gurses HN, Mutluay FK, et al. Effects of home exercises on motor performance in patients with Parkinson's disease. *Clin Rehabil.* 2005;19:870–877.
52. Cakit BD, Saracoglu M, Genc H, et al. The effects of incremental speed-dependent treadmill training on postural instability and fear of falling in Parkinson's disease. *Clin Rehabil.* 2007;21:698–705.
53. Hackney ME, Kantorovich S, Levin R, et al. Effects of tango on functional mobility in Parkinson's disease: a preliminary study. *J Neurol Phys Ther.* 2007;31:173–179.
54. Protas EJ, Mitchell K, Williams A, et al. Gait and step training to reduce falls in Parkinson's disease. *NeuroRehabilitation.* 2005;20:183–190.
55. Schenkman M, Cutson TM, Kuchibhatla M, et al. Exercise to improve spinal flexibility and function for people with Parkinson's disease: a randomized, controlled trial. *J Am Geriatr Soc.* 1998;46:1207–1216.
56. Blaszczyk JW, Orawiec R, Duda-Klodowska D, et al. Assessment of postural instability in patients with Parkinson's disease. *Exp Brain Res.* 2007;183:107–114.
57. Boonstra TA, van der Kooij H, Munneke M, et al. Gait disorders and balance disturbances in Parkinson's disease: clinical update and pathophysiology. *Curr Opin Neurol.* 2008;21:461–471.
58. Hass CJ, Waddell DE, Fleming RP, et al. Gait initiation and dynamic balance control in Parkinson's disease. *Arch Phys Med Rehabil.* 2005;86:2172–2176.
59. Horak FB, Dimitrova D, Nutt JG. Direction-specific postural instability in subjects with Parkinson's disease. *Exp Neurol.* 2005;193:504–521.
60. Ganz DA, Higashi T, Rubenstein LZ. Monitoring falls in cohort studies of community-dwelling older people: effect of the recall interval. *J Am Geriatr Soc.* 2005;53:2190–2194.
61. Copay AG, Subach BR, Glassman SD, et al. Understanding the minimum clinically important difference: a review of concepts and methods. *Spine J.* 2007;7:541–546.

APPENDIX A. AACPDM Level of Evidence Rating Criteria

Level	Intervention (Group) Studies
I	Systematic review of randomized controlled trials (RCTs), large RCT (with narrow confidence intervals) ($n > 100$)
II	Smaller RCTs (with wider confidence intervals) ($n < 100$), systematic reviews of cohort studies "Outcomes research" (very large ecologic studies)
III	Cohort studies (must have concurrent control group), systematic reviews of case control studies
IV	Case series cohort study without concurrent control group (eg, with historical control group), case-control study
V	Expert opinion case study or report bench research expert opinion based on theory or physiologic research, common sense/anecdotes

For a full description of the AACPDM systematic review criteria, see http://www.aacpdm.org/resources/systematicReviewsMethodology.pdf.

APPENDIX B. Strength of Evidence Synthesis

Strong evidence	Provided by consistent, statistically significant findings in outcome measures in at least two high quality Level II studies[a]
Moderate evidence	Provided by consistent statistically significant findings in outcome measures in at least one high quality Level II study and at least one moderate quality Level II or III study[a]
Limited evidence	Provided by consistent, statistically significant findings in at least one high quality Level II study[a] OR Provided by consistent, statistically significant findings in outcome measures in at least two high quality Level III studies[a] (in the absence of high quality Level II studies)
Indicative findings	Provided by consistent, statistically significant findings in outcome and or process measures in at least one high quality Level III study or moderate quality Level II studies[a] (in the absence of high quality Level II studies)
No or insufficient evidence	Indicated by conflicting results (statistically significant positive and negative) results

[a] As determined by the AACPDM scale.