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Progressive resistance training in Parkinson’s disease: a systematic review and meta-analysis

Mikhail Saltychev,1 Esa Bärlund,2 Jaana Paltamaa,3 Niina Katajapuu,4 Katri Laimi1

ABSTRACT

Objectives: To investigate if there is evidence on effectiveness of progressive resistance training in rehabilitation of Parkinson disease.

Design: Systematic review and meta-analysis. Data sources: Central, Medline, Embase, Cinahl, Web of Science, Pedro until May 2014. Randomised controlled or controlled clinical trials. The methodological quality of studies was assessed according to the Cochrane Collaboration’s domain-based evaluation framework. Data synthesis: random effects meta-analysis with test for heterogeneity using the I² and pooled estimate as the raw mean difference.

Participants: Adults with primary/idiopathic Parkinson’s disease of any severity, excluding other concurrent neurological condition.

Interventions: Progressive resistance training defined as training consisting of a small number of repetitions until fatigue, allowing sufficient rest between exercises for recovery, and increasing the resistance as the ability to generate force improves.

Comparison: Progressive resistance training versus no treatment, placebo or other treatment in randomised controlled or controlled clinical trials.

Primary and secondary outcome measures: Any outcome.

Results: Of 516 records, 12 were considered relevant. Nine of them had low risk of bias. All studies were randomised controlled trials conducted on small samples with none or 1 month follow-up after the end of intervention. Of them, six were included in quantitative analysis. Pooled effect sizes of meta-analyses on fast and comfortable walking speed, the 6 min walking test, Timed Up and Go test and maximal oxygen consumption were below the level of minimal clinical significance.

Conclusions: There is so far no evidence on the superiority of progressive resistance training compared with other physical training to support the use of this technique in rehabilitation of Parkinson’s disease.

Systematic review registration number: PROSPERO 2014:CRD42014009844.

INTRODUCTION

Principles of progressive resistance training (PRT) have remained essentially unchanged since 1945–1949, when US Army physician Captain Thomas L. Delorme introduced this technique as an efficient way to rehabilitate soldiers.1,2 For 70 years, PRT has been widely used in rehabilitation of young and physically active people. During the past two decades, use of PRT has also been studied among people with chronic diseases and disabilities3 such as hypertension, chronic obstructive pulmonary disorders, chronic low back and neck pain, osteoarthritis, cerebral palsy, stroke and diabetes. In these conditions, PRT may reduce pain, and improve muscle strength and the level of physical activity without significant side effects.3

The data on the effectiveness of PRT in the rehabilitation of people with Parkinson’s disease are scarce. The conclusions of recent reviews on the topic show inconsistency of inferences. In a recent systematic review by Brienesse et al7 of five randomised controlled trials (RCT), PRT was found to have a positive effect on muscle strength, mobility, endurance, fat-free mass and performance in functional tasks. Another recent systematic review by Lima et al6 of four controlled trials suggested that PRT could be effective in increasing walking capacity in Parkinson’s disease. A narrative review by David et al8 reported a favourable effect of PRT on muscle strength and function and non-motor symptoms of Parkinson’s disease. Also, a narrative review by Falvo et al5 emphasised the lack of robust data on the topic. While Lima et al and David et al ended up with a strong...
conclusion that there is evidence that progressive resistance training should be implemented in Parkinson’s disease rehabilitation, the conclusions of Brienesse et al and Falvo et al indicated more cautiously that data are insufficient to make robust recommendations and further research is needed.

The purpose of this study was to evaluate the evidence on the effectiveness of PRT in the rehabilitation of people with Parkinson’s disease, and to make concrete recommendations for clinical practice.

METHODS

Data sources and searches

Criteria for considering studies for this review were based on the PICO (Population, Intervention, Comparison, and Outcome) framework as follows:

▸ Patients: Adults with primary/idiopathic Parkinson’s disease of any severity, excluding any other concurrent neurological condition.

▸ Intervention: Progressive resistance training defined as training which (A) consists of a small number of repetitions until fatigue, (B) allows sufficient rest between exercises for recovery and (C) increases the resistance as patient’s ability to generate force improves.3

▸ Comparison: Progressive resistance training versus no treatment, placebo or other treatment in randomised controlled or controlled clinical trials.

▸ Outcome: Any outcome.

Cochrane Controlled Trials Register (CENTRAL), MEDLINE (via PubMed), EMBASE, CINAHL, Web of Science and Physiotherapy Evidence (Pedro) databases were searched in May 2014 with no restrictions by date or language. The search clauses are presented in online supplementary file 1. In order to avoid missing relevant studies, the use of limits was restricted and further selection was conducted manually. The references of identified articles and reviews were also checked for relevancy.

Study selection

Two independent reviewers (EB and MS) screened the titles and abstracts of articles, assessed the full texts of potentially relevant studies, and rated the methodological quality of included trials (figure 1).

Disagreements between reviewers were resolved by consensus or by the third reviewer (JP). The more detailed description of the exclusion process is available on request from the corresponding author.

Data extraction and quality assessment

Data needed for meta-analysis were extracted from the included trials using a standardised form based on

![Flow chart of reviewing process.](http://bmjopen.bmj.com/content/6/e008756/F1.large.jpg)
recommendations by the Cochrane Handbook for Systematic Reviews of Interventions V.5.1.0, part 7.6.9 If a study was reported in more than one publication, the information from multiple reports was collated by extracting data from each report separately and then combining the information of all data collection forms.

The methodological quality was assessed according to the Cochrane Collaboration’s domain-based evaluation framework.10 Main domains were assessed in the following sequence: (1) selection bias (randomised sequence generation and allocation concealment); (2) performance bias (blinding of participants and personnel); (3) detection bias (blinding of outcome assessment); (4) attrition bias (incomplete outcome data, eg, due to dropouts); (5) reporting bias (selective reporting); (6) other sources of bias. The scores for each bias domain and the final score of risk of systematic bias were graded as low, high or unclear risk.

Data synthesis and analysis
We used a random effects meta-analysis to quantify the pooled effect size of included studies as a more natural choice than fixed effects in the context of multiple clinical trials conducted in diverse settings. In addition, test for heterogeneity supported this choice. The test for heterogeneity was conducted using the $I^2$ statistic describing the percentage of variation across studies originating more from heterogeneity than from chance. We calculated the non-standardised means of difference in change of means for each study and for the pooled study sample. When the SD of difference of changes of groups’ means was not reported, the coefficient of correlation between prevariance and postvariance was set at 0.6. The potential publication bias was evaluated by Egger’s test for asymmetry of the funnel plot (test for the Y intercept=0 from the linear regression of normalised effect estimate against precision), where the trim-and-fill method was used to impute studies into a funnel plot to correct asymmetry. All calculations for the meta-analysis were performed using MIX 2.0. V2.0.1.4. BiostatXL, 2011, available from http://www.meta-analysis-made-easy.com, Comprehensive Meta Analysis CMA, V2.2.064, available from http://www.meta-analysis.com, and Microsoft Excel 2013.

RESULTS
The search resulted in 516 records. Of them, 297 study reports were removed as being duplicates, conference proceedings, posters, theses, etc. After including five reports found from the reference lists of identified review articles, 224 records were screened on the basis of their titles and abstracts. Of these records, full texts of 58 reports were screened more thoroughly, and 12 were considered relevant for qualitative analysis (details in figure 1). Similarity of outcome measures, needed for meta-analysis, was found among five different reports.11 14 20–22 Additionally, two subgroups in the study by DiFrancisco-Donoghue et al17 (one sample comparing PRT with usual care and another comparing PRT and vitamins with vitamins alone) were used in meta-analysis.

Qualitative analysis of 12 included studies
Table 1 shows the descriptive characteristics of included studies. Publication years varied from 1997 to 2014.

Eight studies were conducted in the USA and four in Australia. The size of the intervention groups at the end of follow-up varied from 6 to 22. Most of the studies only reported pretreatment/post-treatment results. Two of 12 studies also had a short 1 month follow-up after intervention.13 19 In the samples, male gender predominated and the mean age of participants varied from 59 to 71 years. The implementation schemes of PRT varied widely across the studies. The progression of training load was usually defined by one repetition maximum, by participant’s fatigue, or by achieving an agreed amount of repetitions. The duration of intervention varied from 1.5 to 24 months with a frequency of two or three times per week. Of 12 studies, 10 reported a positive effect of intervention. Six studies compared progressive resistance training with weakly defined ‘usual activities’,11–13 16–18 four with different low-intensity strengthening, endurance or balance exercises,14 15 19 20 one with the use of vitamins,17 and one with treadmill training.22 It is self-evident that most of the patients with PD have more than one treatment. Thus, when comparing PRT and vitamins against only vitamins, omitting vitamins was accepted by us as approximation and the study by DiFrancisco-Donoghue et al17 could be included into this review. The outcome measures of included studies spread across a wide spectrum and are presented in online supplementary file 2 along with their reported main results.

The risk of bias was considered low for nine studies and high for three studies (table 2). The most frequent source of potential bias was the performance bias related to the inadequate or insufficiently reported blinding procedure.

The included studies reported positive effects of PRT on the score of the Freezing of Gait Questionnaire,11 oxidative stress,12 gait velocity and endurance,14 the scores of Parkinson’s Disease Rating Scale and Modified Fitness Counts,15 cognitive functioning (demonstrating no effect on mood or disease-specific quality of life),16 gait initiation performance18 and muscle strength of trunk and/or lower extremities.13 19–22 One study found PRT to be more effective at increasing glutathione levels and decreasing homocysteine levels compared with controls but without differences when compared with vitamin intake.17

Meta-analyses of six included studies
The risk of bias of all six studies was considered low. Five different meta-analyses were conducted on two to four samples sized from 6 to 22 participants each. When


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<table>
<thead>
<tr>
<th>Study/year/country</th>
<th>Cases/controls, N (% men)</th>
<th>Intensity and duration</th>
<th>Control treatment</th>
<th>Response to treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Allen 2010 Australia</strong></td>
<td>24 (54)/24 (54)</td>
<td>Progressive lower limb strengthening and balance exercises (a monthly exercise class, remaining exercise sessions at home). Standardised falls prevention advice (booklet)</td>
<td>40–60 min 3 times per week for 6 months</td>
<td>Insignificant difference</td>
</tr>
<tr>
<td><strong>Bloomer 2008 USA</strong></td>
<td>8 (50)/8 (50)</td>
<td>Three sets of 5–8 repetitions: leg press, leg curl and calf press. Increased weight by 5–10% when 8 repetitions were completed for all 3 sets</td>
<td>Two times per week for 2 months</td>
<td>Positive</td>
</tr>
<tr>
<td><strong>Bridgewater 1997 Australia</strong></td>
<td>13 (69)/13 (54)</td>
<td>15 min warm-up. Trunk muscles (back extensors and abdominals): 10 repetitions of 7 s isometric contractions with 7 s rest. Progression: as individual ability and improvement allowed</td>
<td>Two times per week for 3 months</td>
<td>Positive</td>
</tr>
<tr>
<td><strong>Combs 2013 USA</strong></td>
<td>17 (65)/14 (71)</td>
<td>15 min warm-up. Boxing circuit, endurance. Progression: self-progressed by completing more repetitions during each training bout as intensely as tolerated</td>
<td>24–36×90 min for 3 months</td>
<td>Positive</td>
</tr>
<tr>
<td><strong>Corcos 2013 USA</strong></td>
<td>24 (58)/24 (58)</td>
<td>Strength: 1–3 sets of 8×6–9 s repetitions; speed: 2 sets of 12 repetitions. Progression: 5% depending on one repetition maximum</td>
<td>Two times per week for 24 months</td>
<td>Positive</td>
</tr>
<tr>
<td><strong>Cruise 2011 Australia</strong></td>
<td>15 (60)/13 (69)</td>
<td>5 min warm-up (walking, stationary cycling and stretching), 6 resistance exercises. Progression: 5–10% based on one repetition maximum</td>
<td>60 min 2 times per week for 3 months</td>
<td>Positive</td>
</tr>
<tr>
<td><strong>DiFrancisco-Donoghue 2012 USA</strong></td>
<td>10 (77)/9 (33) †</td>
<td>20 min aerobic exercise, weight training 2 sets of 8–15 repetitions with 30 s rest between. Progression: weight increased by 5 lbs when 15 repetitions per set were achieved</td>
<td>40 min 2 times per week for 1½ months</td>
<td>Insignificant difference</td>
</tr>
<tr>
<td><strong>Hass 2012 USA</strong></td>
<td>9 (77)/9 (77)</td>
<td>5 min warm-up, 2 sets of 12–20 repetitions of six exercises, 5 min break between sets. Progression based on one repetition maximum</td>
<td>Two times per week for 2½ months</td>
<td>Positive</td>
</tr>
<tr>
<td><strong>Hirsch 2003 USA</strong></td>
<td>6/9</td>
<td>Balance+resistance training. Resistance training: 15 min lower extremities, 1 set of 12 repetitions, and 2 min rest between</td>
<td>Three times per week for 2½ months</td>
<td>Balance training Positive</td>
</tr>
<tr>
<td>Study/year/country</td>
<td>Cases/controls, N (% men)</td>
<td>Age *</td>
<td>Case treatment</td>
<td>Intensity and duration</td>
</tr>
<tr>
<td>--------------------</td>
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</tr>
<tr>
<td>Paul 2014 Australia</td>
<td>20 (65)/20 (60)</td>
<td>68/65</td>
<td>Three sets of 8 repetitions maximum</td>
<td>45 min 2 times per week for 3 months</td>
</tr>
<tr>
<td>Schilling 2010 USA</td>
<td>9/9</td>
<td>61/57</td>
<td>Warm-up, 3 sets of 5–8 repetitions of the leg press, leg curl and calf press. Progression: when 8 repetitions for all 3 sets were completed, the weight was increased by 5–10%</td>
<td>Two times per week for 2 months</td>
</tr>
<tr>
<td>Shulman 2013 USA</td>
<td>28††/26††</td>
<td>65††/66††</td>
<td>Resistance exercises: 2 sets of 10 repetitions (leg press, leg extension and leg curl). Progression: weight increased as tolerated</td>
<td>Three times per week for 3 months</td>
</tr>
</tbody>
</table>

*Years in means.
†Training versus controls.
‡Training and vitamins versus vitamins.
§Strength.
¶Balance.
**Mobility and balance.
††Stretching and Resistance Training.
‡‡Lower-Intensity treadmill training (higher-intensity treadmill excluded as progressive training of different type).
The pooled effect size was statistically insignificant. The I² was 0%, indicating insignificant heterogeneity.

The effect of PRT on fast walking speed was assessed by pooling samples of four studies. The pooled sample consisted of 49 cases versus 55 controls. The pooled effect size was 0.06 m (95% CI 0.02 to 0.11) in favour of intervention, but below the minimal detectable change of 0.25 m as suggested previously. The I² was 61%, indicating substantial heterogeneity.

The effect of PRT on comfortable walking speed was assessed by pooling samples of four studies. The pooled sample consisted of 60 cases versus 66 controls. The pooled effect size was 0.03 m (95% CI 0.01 to 0.05) in favour of intervention, but below the minimal detectable change of 0.18 m as suggested previously. The I² was 15%, indicating insignificant heterogeneity.

The effect of PRT on comfortable walking speed was assessed by pooling samples of three studies. The size of pooled sample was 26 cases versus 29 controls. The pooled effect size was statistically insignificant −0.71 s (95% CI −1.47 to 0.06) in favour of intervention and below the minimal detectable change of 3.5 s as suggested previously. The I² was 0%, indicating insignificant heterogeneity.

The effect of PRT on the 6 min walk test was assessed by pooling samples of three studies. The pooled sample was 42 cases versus 42 controls. The pooled effect size was 16.67 m (95% CI 7.86 to 25.48) in favour of intervention, but below the minimal detectable change of 82 m as suggested previously. The I² was 61%, indicating substantial heterogeneity.

The effect of PRT on maximal oxygen consumption was assessed by pooling samples of two studies including three samples: two different samples from the study by DiFrancisco-Donoghue et al and one sample from the study by Shulman et al. The pooled sample was 40 cases versus 40 controls. The pooled effect size was −1.6 mL/kg/min (95% CI −1.93 to −1.27) in favour of intervention and below the minimal clinically significant difference of 2 mL/kg/min as suggested previously. The I² was 85%, indicating substantial heterogeneity.

Discrimination for asymmetry of the funnel plot did not reveal a potential publication bias in any of the syntheses.

**DISCUSSION**

In this systematic review of 12 RCTs, no evidence was found on the superiority of PRT in the rehabilitation of people with idiopathic Parkinson’s disease when compared to other training or to usual activities. Few studies conducted on small sample sizes with short periods of follow-up reported some positive effects of PRT on freezing symptoms, gait, cognitive performance and muscle strength. Meta-analyses of these studies did not find clinically significant effects of PRT on walking speed, walking distance, Timed Up and Go test or aerobic performance.

The case and control treatments, as well as intensity, duration and frequency of PRT, employed in the selected studies were diverse and sometimes hardly comparable. The included studies have been conducted on relatively small samples and the effects were followed up for only a few months at most. In this review, a ‘small number of repetitions’ was defined according to the classic work of DeLorme and Watkins in 1948. The use of a more precise definition given by the American College of Sports Medicine, defining a ‘small number of repetitions’ as ≤12 repetitions, might alter our results. Owing to the uncertain definition of PRT, it is possible that some relevant studies remained undetected. However, we used very wide search clauses and performed the rest of the search and selection manually in order to avoid missing the potentially relevant reports.
<table>
<thead>
<tr>
<th>Outcome (units), study</th>
<th>Cases, mean (SD)</th>
<th>Controls, mean (SD)</th>
<th>Effect size</th>
<th>Raw mean difference</th>
<th>95% CI</th>
<th>I² (%)</th>
<th>Egger’s regression</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline Follow-up N</td>
<td>Baseline Follow-up N</td>
<td>Intercept 95% CI</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fast walking speed (ms)</td>
<td>1.47 (0.38) 21</td>
<td>1.54 (0.35) 24</td>
<td>0.06</td>
<td>0.02 to 0.11</td>
<td>61</td>
<td>−3.27</td>
<td>−69.0 to 62.4</td>
</tr>
<tr>
<td>Allen et al 11</td>
<td>1.61 (0.35) 6</td>
<td>1.48 (0.43) 9</td>
<td>0.2</td>
<td>−0.001 to 0.40</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Paul et al 20</td>
<td>−0.02 (0.16)* 6</td>
<td>−0.01 (0.19)* 9</td>
<td>0.01</td>
<td>−0.18 to 0.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shulman et al 22†</td>
<td>0.84 (0.05) 22</td>
<td>0.85 (0.05) 22</td>
<td>0.06</td>
<td>0.03 to 0.09</td>
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<tr>
<td>Comfortable walking speed (ms)</td>
<td>1.07 (0.27) 21</td>
<td>1.04 (0.25) 24</td>
<td>0.0</td>
<td>−0.15 to 0.15</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Allen et al 11</td>
<td>1.09 (0.26) 11</td>
<td>1.06 (0.32) 11</td>
<td>0.03</td>
<td>−0.65 to 0.71</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Paul et al 20</td>
<td>−0.06 (0.16)* 6</td>
<td>−0.05 (0.12)* 9</td>
<td>0.01</td>
<td>−0.13 to 0.15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shulman et al 22‡</td>
<td>0.72 (0.05) 22</td>
<td>0.73 (0.04) 22</td>
<td>0.03</td>
<td>0.01 to 0.05</td>
<td></td>
<td></td>
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<tr>
<td>Timed Up and Go Test (s)</td>
<td>−0.71 (15.12) 11</td>
<td>7.64 (7.39) 11</td>
<td>−0.41</td>
<td>9.04 to 8.22</td>
<td>0</td>
<td>−5.28</td>
<td>−61.1 to 50.5</td>
</tr>
<tr>
<td>Combs et al 14</td>
<td>7.12 (14.62) 11</td>
<td>7.12 (5.47) 11</td>
<td>−1.2</td>
<td>−3.57 to 1.17</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paul et al 20</td>
<td>−1.3 (2.7)* 6</td>
<td>−0.1 (2.0)* 9</td>
<td>−0.65</td>
<td>−0.47 to 0.06</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Schilling et al 21†</td>
<td>5.8 (0.50) 9</td>
<td>7.5 (1.18) 9</td>
<td>−0.65</td>
<td>−0.47 to 0.06</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>6 min walk (m)</td>
<td>16.67 (549.1) 11</td>
<td>478.7 (183.9) 11</td>
<td>57.7</td>
<td>−300.21 to 415.6</td>
<td>47</td>
<td>−6.14</td>
<td>−42.8 to 30.5</td>
</tr>
<tr>
<td>Combs et al 14</td>
<td>457.0 (669.7) 11</td>
<td>478.7 (183.9) 11</td>
<td>57.7</td>
<td>−300.21 to 415.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paul et al 20</td>
<td>−1.3 (2.7)* 6</td>
<td>−0.1 (2.0)* 9</td>
<td>−0.65</td>
<td>−0.47 to 0.06</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schilling et al 21†</td>
<td>537.7 (88.1) 9</td>
<td>493.9 (64.3) 9</td>
<td>24.1</td>
<td>−39.97 to 88.17</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximal oxygen consumption (mL/kg/min)</td>
<td>−1.6 (14.6)* 22</td>
<td>49.1 (15.5)* 22</td>
<td>16.5</td>
<td>7.86 to 25.48</td>
<td>85</td>
<td>26.18</td>
<td>−103.5 to 155.9</td>
</tr>
<tr>
<td>DiFrancisco-Donoghue et al 17¶</td>
<td>13.3 (2.7) 9</td>
<td>12.8 (2.9) 9</td>
<td>−1.5</td>
<td>−3.74 to 0.74</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paul et al 20</td>
<td>11.6 (2.4) 9</td>
<td>12.8 (2.9) 9</td>
<td>−1.5</td>
<td>−3.74 to 0.74</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shulman et al 22§</td>
<td>−0.052 (0.4)* 22</td>
<td>1.53 (0.7)* 22</td>
<td>−1.6</td>
<td>−1.93 to −1.25</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Change from baseline for each group.
†Converted from seconds (50 feet distance) to ms.
‡Converted from seconds (10 m distance) to ms.
§Converted from feet to metres.
¶Exercise versus controls.
**Exercise+vitamins versus vitamins.
The data from the included records were extracted by one researcher, which might affect the objectivity of the process, even if the data extracted were presented to all the authors for the discussion and approved.

When compared to recent systematic reviews on the topic, we identified considerably more relevant studies. The reason for being able to identify more relevant reports than previous reviews on the topic did probably the fact that the search we performed used very few limits, relying on the manual (though time-consuming) fine-tuning of initial search results. Our results are in line with a recent review by Brienesse et al which reported lack of evidence on the effectiveness of PRT. We ended up, however, with a more robust conclusion that, based on several small-sample good-quality RCTs, there is limited evidence on PRT being no more effective in Parkinson’s disease than other physical training schemes. In contrast to our finding, a review by Lima et al suggested that “progressive resistance training should be implemented in Parkinson’s disease rehabilitation” and a review by David et al concluded that “…there is a strong rationale for the use of PRE [progressive resistance exercise] as an adjunct treatment in PD [Parkinson’s disease] …” Such strong recommendations cannot be supported by our results. Since there is no evidence on the superiority or better safety of one specific training scheme over another in patients with PD, rehabilitation providers may include or avoid PRT depending on the settled practice and costs of a particular rehabilitation programme.

In our review, the risk of bias was considered low in 9 of 12 studies. Problems, however, arise from other than methodological issues covered by the scale we used. It is likely that the included studies had insufficient statistical power, undetermined clinical significance and mostly insufficiently described treatment in control groups. They also differed in the degree of disease severity. Implemented schemes of PRT varied from weightlifting to boxing exercises. Even if a study was methodologically well planned and executed, the level of statistical significance is rarely achieved in small samples. Only very large treatment effect sizes could be detected in trials with 20 or less participants. Additionally, statistically significant results, if observed, may not exceed the level of clinical significance, and this should also be taken into account when making clinical recommendations. For example, our meta-analyses on fast and comfortable walking speed and maximal oxygen consumption showed statistical but not clinical significance of pooled effect sizes. The statistically significant pooled effect size observed in meta-analysis on the 6 min walk test fell below the level of minimal detectable change for this test. Unexpectedly, none of the trials followed the effects of PRT for more than 1 month after the end of a supervised training programme. It has been reported previously that the beneficial effects of training may persist for several months after the cessation of training.

The most common source of potential systematic bias in the selected studies was the lack of blinding of participants and personnel. This source of bias is hardly avoidable when physical therapy is involved as the involvement is based on the close participation of the patient and the therapist in the entire chain of planning, performing and assessing the intervention. While it is barely preventable, it could be statistically controlled, for example, by using repeated measures of expectancy and beliefs about the demands of the research throughout the trial.

The search was a year old at the time of accepting this review for publication. Thus, the additional verifying search was conducted on Pubmed seeking relevant papers published between April 2014 and October 2015 and using the same clauses as did previous search. Only one potentially relevant trial was identified. That RCT by Prodoehl et al compared the effects of progressive resistance exercises and a modified Fitness Counts program on the physical function of people with moderate PD. That study used the subset of data used previously in the paper by Corcos et al included in our analysis. The main outcome used by Prodoehl et al included a Modified Physical Performance Test, five times sit to stand test, Functional Reach Test, Timed Up and Go, Berg Balance Scale, 6 min walk test and 50 feet walking speed. In a 2-year follow-up, both groups showed improvements across all studied outcome measures, except for the 6 min walk test without significant differences between treatment methods. It is reasonable to assume that the findings of that trial would not affect our main results.

To make definite clinical recommendations possible, further research should focus on randomised trials on larger sample sizes and with sufficient follow-up periods after the end of the intervention. The safety of PRT in a target population should also be evaluated in comparison with other types of physical training. Further studies may also reveal the effects of resistance training on such important outcome measures as quality of life, activities of daily living, cost-effectiveness, and muscle strength, which are left out of the scope of this review.

Conclusions

Even if physical training is important for health and functioning, there is so far no evidence on the superiority of progressive resistance training compared with other treatments to support the use of this technique in rehabilitation of idiopathic Parkinson’s disease. There is limited evidence on progressive resistance training being ineffective in Parkinson’s disease compared with other physical training schemes.

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