Falls in Parkinson Disease: Causes, Prediction, and Prevention

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Gammon Earhart, PT, PhD ³

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²Professor, Department of Neurology, Department of Biomedical Engineering, Department of Physiology and Pharmacology, Oregon Health & Sciences University

³Professor, Program in Physical Therapy, Department of Neurology, Department of Anatomy & Neurobiology, Washington University School of Medicine
Disclosures

- Ryan Duncan, PT, DPT
  - None

- Fay Horak, PT, PhD
  - Serves as a board member for APDM, Inc.

- Gammon Earhart, PT, PhD
  - None
Objectives

• Describe the multi-faceted nature of postural instability and identify key balance impairments associated with fall risk in people with Parkinson disease (PD).

• Identify risk factors related to falls and describe various outcome measures and their accuracy in predicting falls in people with PD.

• Understand the current evidence regarding the use of exercise to reduce falls and fall risk factors in people with PD.
Outline

• Incidence of and risk factors for falling in PD (Duncan)

• Facets of postural instability in PD (Horak)

• Outcome measures and their properties related to accuracy of predicting falls in PD (Earhart)

• Effectiveness of exercise for reducing postural instability and falls in PD (Duncan)
Parkinson Disease (PD)

- Progressive, neurodegenerative movement disorder
  - Resting tremor, bradykinesia, rigidity, postural instability

- Affects approximately 1.5 million Americans

- World-wide, the number of people affected by PD expected to double between 2005 and 2030

Dorsey ER, *Neurology*, 2007
Incidence of Falls in PD

• 45-68% of people with PD fall annually

• Approximately 66% of those who fall do so recurrently

• Falls expected to become “major health problem” with anticipated increase in number of individuals with PD

  • Canning CG et al. *Neurodegen Dis Manag.* 2014. (p.204)
Consequences of Falls in PD

Adapted from Bloem et al., 2001, Adv Neurol, 87: 209-22
Risk Factors for Falls in PD

- Cognitive impairment
  - Global (i.e. MMSE), Executive Function, Attention, Central Processing
- Depression
- Anxiety
- Prior history of falls
- Balance impairment
  - Static
  - Dynamic
- Freezing of gait / gait impairment
- Physical activity
- Reduced lower extremity strength / power
- Difficulty with ADLs

Potential to be directly modified by physical therapists

Insert Fay’s Slides here
Vicious Cycle

- What is the best way to predict falls in hopes of breaking this cycle?

Adapted from Bloem et al., 2001, Adv Neurol, 87: 209-22
History Repeats Itself

- Best predictor of falls = prior history of falls
  (Pickering RM, Mov Disord, 2007, meta-analysis)
Learning from History

### Assessing the probability of falling in people with Parkinson’s disease

<table>
<thead>
<tr>
<th>Step</th>
<th>Question</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ask your patient: Have you fallen in the past 12 months?</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Yes = 6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No = 0</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Ask your patient: Have you experienced freezing of gait in the past month?</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Yes = 3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No = 0</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Time your patient walking over the middle 4 m of a 6 m walkway at a</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>comfortable pace:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;3.6 s to walk 4 m = ‘yes’</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yes = 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No = 0</td>
<td></td>
</tr>
</tbody>
</table>

**Total score**

<table>
<thead>
<tr>
<th>Total score</th>
<th>Probability of falling in next 6 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Low (17%)</td>
</tr>
<tr>
<td>2–6</td>
<td>Moderate (51%)</td>
</tr>
<tr>
<td>8–11</td>
<td>High (85%)</td>
</tr>
</tbody>
</table>

Tick appropriate box

Paul et al., Mov Disord, 2013
TLI: Too Little Information

- Knowing only fall history, FOG status and gait speed gives little direction for intervention

- Need for standardized outcome measures that:
  - Measure constructs related to falling
  - Are accurate in identifying those at risk and not at risk for falls
  - Are feasible for clinical implementation
Old Faithful? Berg Balance Scale

- Berg Balance Scale commonly used to assess balance in people with PD
  - Ceiling effect
  - 1 faller received a perfect score
  - Other fallers (n=5) were in top 10% of BBS scores

<table>
<thead>
<tr>
<th></th>
<th>Overall (n=80)</th>
<th>Fallers (n=25)</th>
<th>Nonfallers (n=55)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>68.2 ± 9.3</td>
<td>68.8 ± 7.8</td>
<td>67.9 ± 10.0</td>
</tr>
<tr>
<td>% Male</td>
<td>59</td>
<td>64</td>
<td>56</td>
</tr>
<tr>
<td>H &amp; Y Stage</td>
<td>2.45 ± 0.64</td>
<td>2.9 ± 0.71</td>
<td>2.3 ± 0.50</td>
</tr>
</tbody>
</table>

Leddy et al., Phys Ther, 2011
New Faithful? FGA or BESTest

Leddy et al., Phys Ther, 2011
## New Faithful? FGA or BESTest

<table>
<thead>
<tr>
<th>Balance Assessment Measure</th>
<th>AUC (95% CI)</th>
<th>Score</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>LR+ (95% CI)</th>
<th>LR− (95% CI)</th>
<th>Posttest Probability With Test ≤ Cutoff Value</th>
<th>Posttest Probability With Test &gt; Cutoff Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BBS</td>
<td>0.79 (0.68–0.91)</td>
<td>≤47/56*</td>
<td>0.72</td>
<td>0.75</td>
<td>2.83 (1.69–4.73)</td>
<td>0.38 (0.20–0.72)</td>
<td>56.3%</td>
<td>14.6%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≤52/56</td>
<td>0.92</td>
<td>0.47</td>
<td>1.74 (1.32–2.30)</td>
<td>0.17 (0.04–0.66)</td>
<td>44.2%</td>
<td>7.1%</td>
</tr>
<tr>
<td>FGA</td>
<td>0.80 (0.69–0.90)</td>
<td>≤15/30*</td>
<td>0.72</td>
<td>0.78</td>
<td>3.24 (1.86–5.65)</td>
<td>0.36 (0.19–0.69)</td>
<td>59.6%</td>
<td>14.1%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≤27/30</td>
<td>1.00</td>
<td>0.19</td>
<td>1.23 (1.08–1.39)</td>
<td>0.00 (unable to calculate)</td>
<td>35.8%</td>
<td>0.0%</td>
</tr>
<tr>
<td>BESTest</td>
<td>0.85 (0.77–0.94)</td>
<td>≤69%*</td>
<td>0.84</td>
<td>0.76</td>
<td>3.49 (2.11–5.77)</td>
<td>0.21 (0.09–0.52)</td>
<td>61.3%</td>
<td>8.7%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≤84%</td>
<td>1.00</td>
<td>0.39</td>
<td>1.64 (1.32–2.02)</td>
<td>0.00 (unable to calculate)</td>
<td>42.7%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

Leddy et al., Phys Ther, 2011
A Small Improvement: The MiniBESTest

Leddy et al., J Neurol Phys Ther, 2011
Prospective Fall Prediction in PD

• BESTest, Mini-BESTest, BBS, and FGA administered at baseline (n=80)

• Fall history obtained six months and 12 months from baseline assessment

Duncan et al., Parkinsons Dis, 2012
Prospective Fall Prediction in PD

Six-month ROC curves

Sensitivity

1 -specificity

Mini-BESTest
BESTest
BBS
FGA

Duncan et al., Parkinsons Dis, 2012
## Prospective Fall Prediction in PD

(a) Predictive values at 6 months.

<table>
<thead>
<tr>
<th>Balance measure</th>
<th>AUC (95% CI)</th>
<th>Score</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>LR + (95% CI)</th>
<th>LR - (95% CI)</th>
<th>Posttest probability with test ≤ cutoff value</th>
<th>Posttest probability with test &gt; cutoff value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BESTest</td>
<td>0.89 (0.74–0.95)</td>
<td>≤69%</td>
<td>0.93</td>
<td>0.84</td>
<td>5.81 (3.69–9.14)</td>
<td>0.08 (0.04–0.17)</td>
<td>0.69</td>
<td>0.03</td>
</tr>
<tr>
<td>Mini-BESTest</td>
<td>0.87 (0.72–0.94)</td>
<td>≤20/32(63%)</td>
<td>0.86</td>
<td>0.78</td>
<td>3.97 (2.68–5.70)</td>
<td>0.18 (0.11–0.78)</td>
<td>0.60</td>
<td>0.07</td>
</tr>
<tr>
<td>BBS</td>
<td>0.87 (0.75–0.95)</td>
<td>≤47/56</td>
<td>0.79</td>
<td>0.86</td>
<td>5.64 (3.43–9.27)</td>
<td>0.24 (0.17–0.36)</td>
<td>0.68</td>
<td>0.09</td>
</tr>
<tr>
<td>FGA</td>
<td>0.80 (0.62–0.90)</td>
<td>≤15/30</td>
<td>0.64</td>
<td>0.81</td>
<td>3.37 (2.19–5.18)</td>
<td>0.44 (0.34–0.59)</td>
<td>0.56</td>
<td>0.15</td>
</tr>
</tbody>
</table>

Duncan et al., Parkinsons Dis, 2012
Prospective Fall Prediction in PD

Twelve-month ROC curves

- Mini-BESTest
- BBS
- BESTest
- FGA

Duncan et al., Parkinsons Dis, 2012
## Prospective Fall Prediction in PD

(b) Predictive values at 12 months.

<table>
<thead>
<tr>
<th>Balance Measure</th>
<th>AUC (95% CI)</th>
<th>Score</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>LR + (95% CI)</th>
<th>LR – (95% CI)</th>
<th>Posttest Probability with Test ≤ Cutoff Value</th>
<th>Posttest Probability with Test &gt; Cutoff Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BESTest</td>
<td>0.68 (0.45–0.83)</td>
<td>≤69%</td>
<td>0.46</td>
<td>0.74</td>
<td>1.77 (1.19–2.62)</td>
<td>0.73 (0.59–0.91)</td>
<td>0.46</td>
<td>0.26</td>
</tr>
<tr>
<td>Mini-BESTest</td>
<td>0.77 (0.55–0.89)</td>
<td>≤20/32 (63%)</td>
<td>0.62</td>
<td>0.74</td>
<td>2.37 (1.66–3.34)</td>
<td>0.52 (0.39–0.68)</td>
<td>0.53</td>
<td>0.20</td>
</tr>
<tr>
<td>BBS</td>
<td>0.68 (0.45–0.82)</td>
<td>≤47/56</td>
<td>0.46</td>
<td>0.81</td>
<td>2.42 (1.53–3.82)</td>
<td>0.67 (0.54–0.82)</td>
<td>0.54</td>
<td>0.24</td>
</tr>
<tr>
<td>FGA</td>
<td>0.70 (0.50–0.83)</td>
<td>≤15/30</td>
<td>0.46</td>
<td>0.81</td>
<td>2.42 (1.53–3.82)</td>
<td>0.67 (0.54–0.82)</td>
<td>0.54</td>
<td>0.24</td>
</tr>
</tbody>
</table>

Duncan et al., Parkinsons Dis, 2012
Table 4. Prediction of Falls in This Study and Previous Studies<sup>a</sup>

<table>
<thead>
<tr>
<th>Measure</th>
<th>Current Study (N=121)</th>
<th>Wrisley and Kumar&lt;sup&gt;7&lt;/sup&gt; (N=35)</th>
<th>Leddy et al&lt;sup&gt;9&lt;/sup&gt; (N=80)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participants</td>
<td>Inpatients with PD</td>
<td>Community-dwelling elderly patients</td>
<td>Nonhospitalized patients with PD</td>
</tr>
<tr>
<td>Follow-up time occurrence</td>
<td>6 mo after enrollment</td>
<td>6 mo after enrollment</td>
<td>6 mo before enrollment</td>
</tr>
<tr>
<td>FGA demarcation point</td>
<td>18</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>AUC</td>
<td>0.84</td>
<td>0.92</td>
<td>0.80</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>80.6%</td>
<td>100%</td>
<td>72%</td>
</tr>
<tr>
<td>Specificity</td>
<td>80%</td>
<td>83%</td>
<td>78%</td>
</tr>
<tr>
<td>Positive likelihood ratio</td>
<td>4.03</td>
<td>5.80</td>
<td>3.24</td>
</tr>
<tr>
<td>Positive predictive value</td>
<td>0.58</td>
<td>0.58</td>
<td></td>
</tr>
<tr>
<td>Negative predictive value</td>
<td>0.92</td>
<td>1.00</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> PD=Parkinson disease, FGA=Functional Gait Assessment, AUC=area under the curve.

Yang et al., Phys Ther, 2014
Figure 2.
Receiver operating characteristic curve for the Functional Gait Assessment score to predict falls. Area under the curve=0.84 (95% confidence interval=0.77–0.91), P<.001.

Yang et al., Phys Ther, 2014
Gait and Falls

• *Walking difficulty strongest predictor of fear of falling* (Lindholm et al., BMC Neurol, 2014)

• *Why not measure gait to assess fall risk?*
Cage Match: MiniBESTest Vs. Gait

Duncan & Earhart, Parkinson’s Disease, 2012
## Cage Match: MiniBEST vs. Gait Velocity

### Table 2: Predictive values and noninferiority comparisons for all outcome measures.

<table>
<thead>
<tr>
<th>Test</th>
<th>AUC</th>
<th>Cutoff score</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>LR+</th>
<th>LR−</th>
<th>Positive posttest probability</th>
<th>Negative posttest probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mini-BEST</td>
<td>0.80</td>
<td>16</td>
<td>0.75</td>
<td>0.79</td>
<td>3.57</td>
<td>0.32</td>
<td>50.18</td>
<td>8.19</td>
</tr>
<tr>
<td>MDS-UPDRS III</td>
<td>0.79</td>
<td>58</td>
<td>0.50</td>
<td>0.88</td>
<td>4.17</td>
<td>0.57</td>
<td>54.02</td>
<td>13.81</td>
</tr>
<tr>
<td>FOGQ</td>
<td>0.78</td>
<td>8</td>
<td>0.58</td>
<td>0.86</td>
<td>4.14</td>
<td>0.49</td>
<td>53.88</td>
<td>12.10</td>
</tr>
<tr>
<td>FWV</td>
<td>0.63</td>
<td>1.17 m/s</td>
<td>0.67</td>
<td>0.72</td>
<td>2.39</td>
<td>0.46</td>
<td>40.29</td>
<td>11.45</td>
</tr>
<tr>
<td>BWV</td>
<td>0.68</td>
<td>0.50 m/s</td>
<td>0.67</td>
<td>0.70</td>
<td>2.23</td>
<td>0.47</td>
<td>38.64</td>
<td>11.73</td>
</tr>
<tr>
<td>DTWV</td>
<td>0.64</td>
<td>0.78 m/s</td>
<td>0.66</td>
<td>0.72</td>
<td>2.36</td>
<td>0.47</td>
<td>39.93</td>
<td>11.75</td>
</tr>
<tr>
<td>FastWV</td>
<td>0.56</td>
<td>1.59 m/s</td>
<td>0.58</td>
<td>0.72</td>
<td>2.07</td>
<td>0.58</td>
<td>36.87</td>
<td>14.13</td>
</tr>
</tbody>
</table>

Duncan & Earhart, Parkinson’s Disease, 2012
Dual Task Debate

Fig. 2  Dual-task costs for the Stroop task plotted against dual-task costs for gait speed for each individual. DT dual task

Smulders et al., J Neurol, 2012
1-second increase in TUG = 5.4% increase in odds of reporting a fall

Nocera et al., APM&R, 2013
<table>
<thead>
<tr>
<th>Variable (Cutoff Time, s)</th>
<th>AUC (95% CI)</th>
<th>% Sensitivity (95% CI)</th>
<th>% Specificity (95% CI)</th>
<th>Positive LR (95% CI)</th>
<th>Negative LR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TUG (12)</td>
<td>0.77 (0.60, 0.89)</td>
<td>41 (32, 51)</td>
<td>73 (64, 82)</td>
<td>1.57 (0.6, 4.1)</td>
<td>0.8 (0.5, 1.3)</td>
</tr>
<tr>
<td>TUG-cognitive (14.7)</td>
<td>0.82 (0.64, 0.92)</td>
<td>76.5 (52, 90.4)</td>
<td>73.7 (51.2, 88.2)</td>
<td>2.9 (1.3, 6.5)</td>
<td>0.32 (0.1, 0.8)</td>
</tr>
<tr>
<td>TUG-manual (13.2)</td>
<td>0.78 (0.61, 0.90)</td>
<td>29.55 (13, 53.1)</td>
<td>68.4 (46, 84.6)</td>
<td>0.9 (0.34, 2.5)</td>
<td>1.1 (0.67, 1.6)</td>
</tr>
</tbody>
</table>

*AUC = area under the curve, CI = confidence interval, TUG-cognitive = TUG with an added cognitive task, TUG-manual = TUG with an added manual task.*

Vance et al., Phys Ther, 2014
Pull Test – UPDRS

K.B. Foreman et al. / Parkinsonism and Related Disorders 17 (2011) 166–171
MDS-UPDRS-III

ROC Curve

Sensitivity

1 - Specificity

Mak & Auyeung, J Rehab Med, 2013

Diagonal segments are predicted by ties
Table III. Results of multivariate logistic regression for risk factors for predicting recurrent falls in Parkinson’s disease

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>B</th>
<th>SE</th>
<th>Odds ratio</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Model 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>-0.027</td>
<td>0.034</td>
<td>0.973</td>
<td>0.426</td>
</tr>
<tr>
<td>Gender</td>
<td>-0.594</td>
<td>0.612</td>
<td>0.552</td>
<td>0.331</td>
</tr>
<tr>
<td>Duration of PD</td>
<td>0.061</td>
<td>0.053</td>
<td>1.063</td>
<td>0.246</td>
</tr>
<tr>
<td>HY</td>
<td>1.736</td>
<td>0.702</td>
<td>5.677</td>
<td>0.013*</td>
</tr>
<tr>
<td>Prior fall history</td>
<td>2.367</td>
<td>0.715</td>
<td>10.665</td>
<td>0.001*</td>
</tr>
<tr>
<td>GDS</td>
<td>0.041</td>
<td>0.074</td>
<td>1.042</td>
<td>0.581</td>
</tr>
<tr>
<td><strong>Model 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>-0.038</td>
<td>0.037</td>
<td>0.963</td>
<td>0.305</td>
</tr>
<tr>
<td>Gender</td>
<td>-0.923</td>
<td>0.668</td>
<td>0.397</td>
<td>0.167</td>
</tr>
<tr>
<td>Duration of PD</td>
<td>0.061</td>
<td>0.053</td>
<td>1.063</td>
<td>0.242</td>
</tr>
<tr>
<td>HY</td>
<td>2.231</td>
<td>0.930</td>
<td>9.309</td>
<td>0.016*</td>
</tr>
<tr>
<td>Prior fall history</td>
<td>2.353</td>
<td>0.782</td>
<td>10.521</td>
<td>0.003*</td>
</tr>
<tr>
<td>GDS</td>
<td>0.018</td>
<td>0.081</td>
<td>1.018</td>
<td>0.824</td>
</tr>
<tr>
<td>MDS-UPDRS III</td>
<td>0.065</td>
<td>0.042</td>
<td>0.937</td>
<td>0.127</td>
</tr>
<tr>
<td>FOGQ</td>
<td>0.000</td>
<td>0.050</td>
<td>1.000</td>
<td>0.992</td>
</tr>
<tr>
<td>FTSTS</td>
<td>0.060</td>
<td>0.034</td>
<td>1.062</td>
<td>0.082</td>
</tr>
<tr>
<td><strong>Model 3</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>-0.072</td>
<td>0.043</td>
<td>0.931</td>
<td>0.092</td>
</tr>
<tr>
<td>Gender</td>
<td>-1.783</td>
<td>0.845</td>
<td>0.468</td>
<td>0.135</td>
</tr>
<tr>
<td>Duration of PD</td>
<td>0.074</td>
<td>0.055</td>
<td>1.077</td>
<td>0.181</td>
</tr>
<tr>
<td>HY</td>
<td>1.223</td>
<td>1.082</td>
<td>3.396</td>
<td>0.258</td>
</tr>
<tr>
<td>Prior fall history</td>
<td>2.188</td>
<td>0.761</td>
<td>8.917</td>
<td>0.004*</td>
</tr>
<tr>
<td>GDS</td>
<td>-0.034</td>
<td>0.091</td>
<td>0.967</td>
<td>0.708</td>
</tr>
<tr>
<td>MDS-UPDRS III</td>
<td>-0.099</td>
<td>0.050</td>
<td>0.906</td>
<td>0.048*</td>
</tr>
<tr>
<td>FOGQ</td>
<td>0.013</td>
<td>0.053</td>
<td>1.013</td>
<td>0.810</td>
</tr>
<tr>
<td>FTSTS</td>
<td>0.034</td>
<td>0.037</td>
<td>1.034</td>
<td>0.368</td>
</tr>
<tr>
<td>Mini-BESTest score</td>
<td>-0.287</td>
<td>0.117</td>
<td>0.750</td>
<td>0.014*</td>
</tr>
</tbody>
</table>

**Fig. 2.** Receiver operating characteristic (ROC) curves for multivariate models used to predict Parkinson’s disease recurrent fallers.

Mak & Auyeung, J Rehab Med, 2013
Fall-Risk Assessment

- Nothing is perfect

- Use the full picture (i.e. don’t rely solely on balance measures)
  - Collective interpretation of multiple balance tests has positive results (Dibble LE Phys Ther 2008)

- Ideal world:
  - Twice yearly PT evaluation (Duncan et al. Parkinson’s Dis 2012)
  - Patients would be tested on and off anti-PD medication (Dibble LE Parkinsonism Relat Disord 2011)
Prevention of falls in Parkinson’s disease: a review of fall risk factors and the role of physical interventions

Colleen G Canning*1, Serene S Paul1,2 & Alice Nieuwboer3

Practice points

- A three-step clinical tool assessing falls in the past year, freezing of gait in the past month and gait speed can be used to accurately identify level of fall risk in the next 6 months.
- Freezing of gait, impaired balance and impaired cognition are commonly identified, potentially remediable fall risk factors.
- There is emerging evidence to support fully supervised challenging balance exercises performed in groups or individually to reduce falls.
- There is limited evidence for minimally supervised, home-based exercise programs for fall prevention.
- Improvements in mobility and physical activity can be achieved without increasing falls.
- Physical interventions aimed at reducing falls need to be tailored to level of fall risk, as well as fall history (e.g., multiple or injurious falls) and presenting risk factors (e.g., cognitive impairment).
Fall Prevention in PD

• Outline

  • Evidence related to using exercise to reduce actual falls in PD
  • Evidence related to using exercise to modify fall risk factors in PD
  • Implications for physical therapy for those with PD at risk for falling
2 studies included

- No effect of physical intervention on proportion of fallers compared with usual care
- One of the trials included was not designed to reduce falls
Physiotherapy versus placebo or no intervention in Parkinson’s disease (Review)

- Included 4 published full-length papers and 3 published abstracts
  - Non-significant trend noted for reduction in falls reduction with PT
  - No significant difference in fall reduction when comparing to PT to no intervention

• RCT
  
  • Balance training (n=28):
    • Self-destabilization exercise
    • Externally induced destabilization exercise
    • Postural control feedback
  
  • Control (n=27):
    • Joint mobilization, motor coordination exercise, and muscle stretching
  
  • Both groups: 21 sessions, 3x/week, 50 minutes each session
Effect of Balance Training on Postural Instability in Patients With Idiopathic Parkinson’s Disease

Nicola Smania, MD\textsuperscript{1,2}, Elisabetta Corato, MD\textsuperscript{1}, Michele Tinazzi, PhD\textsuperscript{1}, Clementina Stanzani, MD\textsuperscript{1}, Antonio Fiaschi, MD\textsuperscript{1,3}, Paolo Girardi, PhD\textsuperscript{4}, and Marialuisa Gandolfi, MD\textsuperscript{1,2}

Number of Falls Before and After Balance Training

<table>
<thead>
<tr>
<th></th>
<th>Pre-Test</th>
<th>Post-Test</th>
<th>1-Month Follow Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental</td>
<td>4.3 (9.1)</td>
<td>1.3 (4.7)</td>
<td>1.3 (4.7)</td>
</tr>
<tr>
<td>Control</td>
<td>4.6 (8.0)</td>
<td>4.1 (7.3)</td>
<td>4.1 (7.0)</td>
</tr>
</tbody>
</table>

* Values are mean (SD)

- Significant differences between groups (p≤0.001):
  - Pre-test $\rightarrow$ Post-test
  - Pre-test $\rightarrow$ 1-Month Follow Up
Tai Chi and Postural Stability in Patients with Parkinson’s Disease

Fuzhong Li, Ph.D., Peter Harmer, Ph.D., M.P.H., Kathleen Fitzgerald, M.D., Elizabeth Eckstrom, M.D., M.P.H., Ronald Stock, M.D., Johnny Galver, P.T., Gianni Maddalozzo, Ph.D., and Sara S. Batya, M.D.

• RCT

  • Tai Chi (n=65)
    • Six Tai Chi forms for first 10 weeks, then progressed to 8-form routine

  • Resistance Training (n=65)
    • Lower extremity strength (1-3 sets, 10-15 reps): hip, knee, ankle
    • Weighted vest added at week 10, 1% BW → 5% BW

  • Stretching (n=65)
    • Active control group - breathing, stretching, relaxation

  • All groups exercised for 60 minutes twice weekly for 6 months

• **Primary Outcome Measures**
  • Maximum excursion (i.e. limits of stability)
  • Directional control (i.e. movement accuracy)

• **Secondary Outcome Measures**
  • Gait – velocity, stride length
  • Knee flexor/extensor strength
  • Functional reach test
  • Timed Up & Go
  • UPDRS III
  • **Falls – daily fall calendars**
Tai Chi and Postural Stability in Patients with Parkinson’s Disease

Fuzhong Li, Ph.D., Peter Harmer, Ph.D., M.P.H., Kathleen Fitzgerald, M.D., Elizabeth Eckstrom, M.D., M.P.H., Ronald Stock, M.D., Johnny Galver, P.T., Gianni Maddalozzo, Ph.D., and Sara S. Batya, M.D.

The NEW ENGLAND JOURNAL of MEDICINE

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### Self-Reported Falls During 6 Month Intervention

<table>
<thead>
<tr>
<th></th>
<th>Tai Chi</th>
<th>Resistance</th>
<th>Stretching</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any (n (%))</td>
<td>19 (29)</td>
<td>31 (48)</td>
<td>26 (40)</td>
</tr>
<tr>
<td>1</td>
<td>3 (5)</td>
<td>8 (12)</td>
<td>4 (6)</td>
</tr>
<tr>
<td>2</td>
<td>4 (6)</td>
<td>7 (11)</td>
<td>2 (3)</td>
</tr>
<tr>
<td>≥ 3</td>
<td>12 (18)</td>
<td>16 (25)</td>
<td>20 (31)</td>
</tr>
<tr>
<td>Rate</td>
<td>0.22</td>
<td>0.51</td>
<td>0.62</td>
</tr>
</tbody>
</table>

- **Incidence Rate**
  - Tai Chi significantly different from stretching (p=0.005)
  - Tai Chi different from resistance (p=0.05)
An exercise intervention to prevent falls in people with Parkinson’s disease: a pragmatic randomised controlled trial

Victoria A Goodwin,1 Suzanne H Richards,1 William Henley,2 Paul Ewings,3 Adrian H Taylor,4 John L Campbell1

• RCT
  • Intervention (n=64)
    • Group strength and balance exercises 1x/weekly for 60 minutes
    • Home exercises twice weekly
    • Usual care at discretion of clinical team
  • Control (n=66)
    • Usual care at discretion of clinical team
  • Intervention period lasted for 10 weeks
  • Usual care – medical/medication management, PT (i.e. exercise advice, provision of walking aids, gait training), OT (i.e. home modifications, provision of aids), or ST.

Goodwin VA, J Neurol, Neurosurg, Psychiatry, 2011
An exercise intervention to prevent falls in people with Parkinson’s disease: a pragmatic randomised controlled trial

Victoria A Goodwin,¹ Suzanne H Richards,¹ William Henley,² Paul Ewings,³ Adrian H Taylor,⁴ John L Campbell¹

Figure adapted from: Goodwin VA, J Neurol, Neurosurg, Psychiatry, 2011
Promotion of physical activity and fitness in sedentary patients with Parkinson’s disease: randomised controlled trial

Marlies van Nimwegen physiotherapist and research scientist¹, Arlène D Speelman physiotherapist and research scientist¹, Sebastiaan Overeem research scientist², Bart P van de Warrenburg medical doctor², Katrijn Smulders research scientist³, Manon L Donije research scientist⁴, George F Borm professor in biostatistics⁵, Frank J G Backx professor in clinical sports medicine⁶, Bastiaan R Bloem professor in neurology⁷, Marten Munneke physiotherapist and associate professor in health care innovation⁸, on behalf of the ParkFit Study Group

• Multifaceted Behavioral Change Program

  • ParkFIT
    • Activity coaching
      • Education related to benefits of physical activity
      • Identifying and overcoming barriers to engaging in physical activity
      • Systematic goal setting using health contract and logbook
      • Stimulation to participate in group exercises
      • Ambulatory monitor data with automated feedback
  
  • ParkSAFE
    • Traditional PT
      • Education related to benefits of PT and safety of movements
      • Active lifestyle not explicitly stimulated

van Nimwegen, BMJ, 2013
Falls measured as adverse events, not a primary or secondary outcome

Participants with one or more fall:

- ParkFit: 62%
- ParkSAFE: 67%

Take home: encouraging physical activity did not result in reduced falls, but also did not increase falls
Risk Factors for Falls in PD

- Cognitive impairment
  - Global (i.e. MMSE), Executive Function, Attention, Central Processing
- Depression
- Anxiety
- Prior history of falls
- Balance impairment
  - Static
  - Dynamic
- Freezing of gait / gait impairment
- Physical activity
- Reduced lower extremity strength / power
- Difficulty with ADLs

Potential to be directly modified by physical therapists

Balance Impairment

Aerobic Exercise
Poliakoff, 2013

PT / Balance Training
Smania, 2010
De Goede, 2013
Ellis, 2005

LE Strengthening
Allen, 2010
Li, 2012
Balance Impairment

LSVT BIG ®

Ebersbach, 2010

Nordic Walking

Reuter, 2011
Balance Impairment

Overground Walking with and without Cues

Allen, 2010
Neiuwboer, 2007
Poliakoff, 2013

Treadmill Walking with and without Cues

Mehrholz, 2010
Frazzitta, 2009

Robotic Treadmill Walking

Picelli, 2013
Balance Impairment

Dance

Duncan, 2012
Earhart, 2009

Tai Chi

Li, 2012
Freezing of Gait / Gait Impairment

• Multi-modal exercise program (Allen, 2010)

• Physical therapy (Tomlinson, 2012)

• Cueing
  • Overground gait (Nieuwboer, 2007)
  • Treadmill (Frazzitta, 2009)

• Dance (Duncan, 2012)
Freezing of Gait

- Multi-modal exercise program
  - Balance exercises
  - Strengthening exercises
  - Cueing exercises (if noted to have freezing)

- 40-60 minutes, 3x/week for 6 months

<table>
<thead>
<tr>
<th>Comfortable Gait Speed (m/sec)</th>
<th>Pre-Test</th>
<th>Post-Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercise (n=21)</td>
<td>1.07 ± 0.27</td>
<td>1.09 ± 0.26</td>
</tr>
<tr>
<td>Control (n=24)</td>
<td>1.04 ± 0.25</td>
<td>1.06 ± 0.32</td>
</tr>
</tbody>
</table>

Allen, Mov Disord, 2010
Freezing of Gait / Gait Impairment

- RESCUE trial
  - Largest cueing trial to date (n=153)
    - Randomized, crossover design
  - 3 week home cueing program using a prototype cueing device
  - Significant improvements in:
    - Gait speed
    - Step length
    - Freezing of Gait severity (5.5% reduction in freezers only)

Nieuwboer, J Neurol Neurosurg Psychiatry, 2007
Freezing of Gait / Gait Impairment

- PD4PD trial
  - Randomized, controlled trial
  - Twice weekly dance classes for one year (Argentine Tango) vs. control group
  - Participants tested OFF anti-PD medication

Duncan, *Neurorehabil Neural Repair*, 2012
Physical Activity

• Cueing training

  • RESCUE trial

    • Participants wore activity monitors while training with cueing devices

• Significant improvements in time spent in static activity, dynamic activity, and walking

• Effects diminished after intervention suggesting need for continued practice

Lim, *Neurorehabil Neural Repair*, 2010
Physical Activity

• Multifaceted Behavioral Change Program
  
  • No difference between groups for change in physical activity and 6 Minute Walk Test
  
  • Significant improvement in number of hours of activity per week and Kcal expenditure per day in experimental group

van Nimwegen, *BMJ*, 2013
Reduced Lower Extremity Strength / Power

• Knee extensor strength
  • Lower limb strength exercises (Lima, 2013; Li, 2012)
  • Treadmill training (Yang, 2010)
  • Tai Chi (Li, 2012)

• Knee flexor strength
  • Lower limb strength exercises (Li, 2012)
  • Tai chi (Li, 2012)

• Leg extensor power
  • Leg muscle power training (Paul, 2014)
Leg muscle power training

- Leg extensors, knee flexors, hip flexors, hip abductors
- 3 sets of 8 repetitions as fast as possible, supervised by PT
- Twice weekly, 45 minutes each session for 12 weeks

Control

- Low intensity exercise of trunk, leg flexors and extensors, and hip abductors at home
- 2 sets of each exercise twice weekly, started at 8 reps per set
  - Increased reps by 2 every 4 weeks

Leg muscle power is enhanced by training in people with Parkinson’s disease: a randomized controlled trial
Serene S Paul¹, Colleen G Canning¹, Jooeun Song¹, Victor SC Fung²,³ and Catherine Sherrington⁴

<table>
<thead>
<tr>
<th>Mean Change in Lower Extremity Power after 12 Weeks</th>
<th>Experimental</th>
<th>Control</th>
<th>p (effect size)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leg Extensors (W)</td>
<td>55.5 ± 63.8</td>
<td>-2.4 ± 38.5</td>
<td>0.002 (1.10)</td>
</tr>
<tr>
<td>Knee Flexors (W)</td>
<td>29.1 ± 39.6</td>
<td>-1.7 ± 23.2</td>
<td>0.01 (0.95)</td>
</tr>
<tr>
<td>Hip Flexors (W)</td>
<td>75.4 ± 94.9</td>
<td>8.6 ± 28.4</td>
<td>0.007 (0.95)</td>
</tr>
<tr>
<td>Hip Abductors (W)</td>
<td>33.4 ± 32.1</td>
<td>-3.2 ± 16.5</td>
<td>&lt;0.001(1.43)</td>
</tr>
</tbody>
</table>

- No significant changes in mobility measures (i.e. gait speed, Timed Up & Go, Freezing of Gait Questionnaire)

Paul, Clin Rehabil, 2014

Program in Physical Therapy
Difficulty with ADLs

- A 16-month program of flexibility, balance, and functional exercises resulted in improved UPDRS II scores compared to a control group.

- Cycle ergometry over 6 weeks led to significant improvement in UPDRS II scores.

- Physical therapy and exercise are also helpful in improving ADL performance.

Schenkman, *Phys Ther*, 2012
Lauhoff, *Disabil Rehabil*, 2013
Implications for PT

- Environment
  - Remove clutter, avoid narrow spaces that may cause freezing
  - Use nightlights
  - Consider prescribing an assistive device

- Be aware of medication side-effects
  - Orthostatic hypotension
  - Hallucinations
  - Impulsivity

- Consider referring to neurologist, OT, SLP when cognitive deficits are present
Conclusions

• Postural instability common in PD; can be measured clinically using the BESTest and/or Mini-BESTest
  
  • Provides system-specific approach to identification of balance impairments

• There is no such thing as a perfect fall risk assessment
  
  • Do not rely solely on balance measures; consider cognition and other tests

• Ideally, patients with PD would receive a twice yearly PT evaluation for assessment of fall risk and change in function
Conclusions

• Limited evidence suggesting that actual falls can be reduced through participation in exercise for those with PD

  • Falls are extremely complex and are not just a factor of physical mobility and performance

• Remediation of fall risk factors is possible with the use of different forms of exercise

  • Suggests regular performance in an exercise program is paramount for those with PD, especially for those at risk for falls
Acknowledgements

• Drs. Horak and Earhart

• Funding sources
  • NIH/NINDS R01 NS077959
  • American Parkinson Disease Association (Greater St. Louis Chapter)
  • Parkinson’s Disease Foundation
  • Davis Phinney Foundation

• Programming Committee of the Neurology Section of the APTA
Questions?