Effects of Whole-Body Vibration on Sensorimotor Performance in People With Parkinson Disease: A Systematic Review

Ricky W.K. Lau, Tilda Teo, Felix Yu, Raymond C.K. Chung, Marco Y.C. Pang

Background. Earlier studies show that whole-body vibration (WBV) has beneficial effects on neuromuscular performance in older adults and may be a viable treatment option for people with Parkinson disease (PD).

Purpose. This systematic review was aimed at determining whether WBV improves sensorimotor performance in people with PD.

Data Sources. The sources used in this review were MEDLINE, the Cumulative Index to Nursing and Allied Health Literature (CINAHL), the Excerpta Medica database (EMBASE), the Cochrane Database of Systematic Reviews, and the Physiotherapy Evidence Database (PEDro) (last searched in April 2010).

Study Selection. Randomized and nonrandomized controlled studies examining the effects of WBV in people with PD were selected. Six studies fulfilled the selection criteria and were included in this review.

Data Extraction. The PEDro score was used to evaluate methodological quality. The effects of WBV on various sensorimotor outcomes were noted.

Data Synthesis. Methodological quality was rated as good for 1 study (PEDro score of 6), fair for 4 studies (PEDro score of 4 or 5), and poor for 1 study (PEDro score of 2). Two studies showed that, compared with no intervention, WBV treatment led to significant reductions in tremor and rigidity, as measured with the Unified Parkinson Disease Rating Scale (UPDRS). The findings for other UPDRS cluster scores were conflicting, however. Two studies showed that longer-term WBV (3–5 weeks) did not result in better sensorimotor outcomes than conventional exercise training.

Limitations. The studies reviewed here are limited by their methodological weaknesses and small, heterogeneous samples.

Conclusions. There is insufficient evidence to prove or refute the effectiveness of WBV in enhancing sensorimotor performance in people with PD (ie, grade D recommendations). More good-quality trials are needed to establish the clinical efficacy of WBV in improving sensorimotor function in people with PD.
People with Parkinson disease (PD) typically have varying degrees of muscular weakness, mobility deficits, postural instability, and other motor impairments (eg, rigidity, tremors), all of which render them highly susceptible to falls.\textsuperscript{1–3} Falls often lead to detrimental consequences, which can be both psychological (eg, fear of falling)\textsuperscript{4} and physical (eg, fragility fractures)\textsuperscript{5,6} in nature. Consequently, researchers have continued to search for intervention strategies that are effective in modifying fall-related risk factors.

Focal muscle vibration has been used in neurological rehabilitation for a long time.\textsuperscript{7} The vibration signals activate the sensory receptors (ie, muscle spindles), thereby inducing reflex muscle activation (ie, tonic vibration reflex)\textsuperscript{8} and potentially resulting in benefits for muscle strength (force-generating capacity). Moreover, the delivery of vibration signals constitutes a form of sensory stimulation. The combination of increased sensory input and muscle activation may lead to the enhancement of other neuromotor functions, such as balance and gait. A recent study showed that a 3-day focal muscle vibration program for the quadriceps muscle can effectively improve stance control and leg muscle power (ability to perform work over time) in older adults.\textsuperscript{9} It also has been demonstrated that rhythmic vibrations applied to trunk muscles can enhance gait speed in patients with PD.\textsuperscript{10} These findings suggest the potential use of vibratory stimulation in patients with deficits in sensorimotor function.

During the past decade, whole-body vibration (WBV) therapy for the rehabilitation of various conditions has gained popularity. In WBV, the vibration signals are delivered via a vibratory platform or chair to expose a larger part of the body to the stimulation. In addition to the potential benefits of WBV for bone health because of the effect of mechanical loading,\textsuperscript{11,12} several studies have shown that WBV is effective in improving muscle strength and postural control in older adults.\textsuperscript{12–22} Consequently, it is easy to understand why researchers have increasingly focused their attention on establishing the clinical efficacy of WBV in patients who have different chronic conditions (eg, stroke, type 2 diabetes, cerebral palsy),\textsuperscript{25–30} who often have deficits in various aspects of sensorimotor function, and who are thus highly susceptible to physical deconditioning and falls.

People with PD may be potential beneficiaries of WBV in view of the many neuromotor deficits commonly observed in this group. A systematic review of the literature examining the effects of such therapy on sensorimotor performance in people with PD was considered timely given the recent increased level of research interest in the application of WBV in this population.

Method

Data Sources and Searches

An extensive literature search of electronic databases, including MEDLINE (1950–April 27, 2010), the Cumulative Index to Nursing and Allied Health Literature (CINAHL) (1982–April 27, 2010), and the Excerpta Medica database (EMBASE) (1980–April 27, 2010), was undertaken to identify relevant articles. A combination of the following key terms was used to perform the literature search: (1) exp Parkinson Disease/ or parkinson disease.mp., (2) parkinsonian disorders.mp. or exp Parkinsonian Disorders/, (3) parkinsonism.mp., (4) parki*.mp., (5) whole body vibration.mp., (6) exp Vibration/ or vibration.mp., (7) vibratory.mp., (8) exp Postural Balance/ or balance.mp., (9) rehabilitation.mp. or exp Rehabilitation/, and (10) exp Physical Therapy Modalities/ or physiotherapy.mp. The Cochrane Database of Systematic Reviews and the Physiotherapy Evidence Database (PEDro)\textsuperscript{31} also were searched (the last search being performed on April 27, 2010) with the key word “vibration.” The reference list of each selected article was examined thoroughly to identify other potential articles that might fulfill our criteria. A forward search with the Science Citation Index was conducted to identify and examine all subsequent articles that referenced the selected articles. Moreover, experts in the field were contacted to identify any additional trials.

Research Question and Study Selection Criteria

The PICO method\textsuperscript{32} was used to define the 4 major components of the research question: patient (P)—patients with PD, intervention (I)—WBV, comparison (C)—conventional therapy or no intervention, and outcome (O)—sensorimotor performance. Thus, this systematic review was aimed at answering the following question: Does WBV therapy lead to better sensorimotor performance outcomes in people with PD than conventional therapy or no intervention?

The eligibility criteria for article selection were formulated on the basis of the foregoing study question. Studies were required to meet the following inclusion criteria:
(1) they had to be randomized or nonrandomized controlled studies of the effects of WBV in people with PD, (2) they had to include a measure of sensorimotor performance (eg, leg muscle strength, balance ability, gait) as 1 of the outcome measures, and (3) they had to be English-language publications. The following types of articles were excluded: (1) studies reported in books, because they are considered a secondary source of information; (2) theses and dissertations; and (3) reports published as conference proceedings, because these may not have undergone a formal peer-review process.

**Data Extraction and Quality Assessment**

The literature search, data extraction, and quality assessment procedures were performed by 2 independent research personnel who are both experienced rehabilitation practitioners and actively involved in research. The titles and abstracts of the selected articles generated by the search strategy described above were first screened to eliminate irrelevant articles. The full text of each of the remaining articles was then reviewed to determine eligibility.

The PEDro scale was used to evaluate the scientific rigor of the selected studies (Tab. 1).³³ It consists of 11 items; the first item assesses external validity (ie, the eligibility criteria are clearly specified), and the response is “yes” or “no.” One point is given for each of the other 10 items evaluating external validity. The PEDro scores range from 0 to 10, with higher scores representing superior methodological quality (9 or 10=excellent, 6–8=good, 4 or 5=fair, and <4=poor).³⁴ The level of evidence reported in each article was determined on the basis of the

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### Table 1.

Methodological Quality Determined With the Physiotherapy Evidence Database (PEDro) Scale

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Turbanski et al⁴⁶</th>
<th>Haas et al⁴⁷</th>
<th>Haas et al⁴⁸</th>
<th>Ebersbach et al⁴⁹</th>
<th>Arias et al⁵⁰</th>
<th>King et al⁵¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eligibility criteria</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Random allocation</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Concealed allocation</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Baseline comparability</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Masking of patients</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Masking of therapists</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Masking of assessors</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Adequate follow-up</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Intention-to-treat analysis</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Between-group comparisons</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Point estimates and variability</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>2</td>
<td>6</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>4</td>
</tr>
</tbody>
</table>

* Numeric values are scores.

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### The Bottom Line

**What do we already know about this topic?**

There is evidence that whole-body vibration therapy can enhance certain aspects of neuromotor function, such as sensory input and muscle activation, in older adults with Parkinson disease.

**What new information does this study offer?**

This systematic review shows that there is insufficient evidence to prove or refute the effectiveness of whole-body vibration in improving sensorimotor function in people with Parkinson disease.

**If you’re a patient, what might these findings mean for you?**

Whole-body vibration should be studied more thoroughly before it can be recommended to treat sensorimotor symptoms in people with Parkinson disease.
PEDro scores and guidelines set by the Centre for Evidence-Based Medicine (level 1b indicated a good-quality randomized controlled trial, and level 2b indicated a poor-quality randomized controlled trial). The opinion of the principal investigator was sought if the data extracted and the PEDro ratings given by the 2 independent researchers were different.

**Data Synthesis and Analysis**

Kappa statistics were used to assess agreement between the 2 raters on article selection and PEDro ratings. For each selected article, the effects of WBV on various sensorimotor outcomes were noted. On the basis of the overall evidence reported in the selected articles, grade recommendations were given for the identified outcomes (ie, A—consistent level 1 studies, B—consistent level 2 studies or extrapolations from level 1 studies, C—level 4 studies or extrapolations from level 2 or 3 studies, and D—level 5 evidence or troublingly inconsistent or inconclusive studies at any level), as described by the Centre for Evidence-Based Medicine. Given the limited number of studies in which the same outcome measures were used and the vast differences in the WBV protocols adopted (see the “Results” section), a meta-analysis was deemed inappropriate.

**Results**

The aforementioned search strategy yielded 6,533 articles (Figure). After initial screening through reading of the titles and abstracts, 18 articles were identified as potentially relevant. After the full text of each of these articles was read, 12 more studies were eliminated (Figure). This process resulted in a total of 6 studies that fulfilled all of the selection criteria and thus were included in the review (Tab. 2). The level of interrater agreement on article screening through reading of the titles and abstracts was good (kappa = 0.75), and that of article selection through reading of the full text of each of the remaining articles was excellent (kappa = 1.00).

**Methodological Quality and Levels of Evidence**

The level of interrater agreement on PEDro ratings was good (kappa = 0.76) (Tab. 1). Overall, only 1 study was considered to be a good-quality trial (PEDro score of 6). None of the studies included intention-to-treat analysis. Masking of the assessors was implemented in only 3 studies. Three studies had small samples (n = 21 or n = 28) (Tab. 2). Therefore, after consideration of the methodological weaknesses of the selected studies, only the study of Haas et al was classified as level 1b; the remaining studies were classified as level 2b.

**Characteristics of Study Populations**

People with idiopathic PD were the target populations in all of the selected studies (Tab. 2). The sample sizes varied from 21 to 68, and the mean ages ranged from 63.1 to 75.0 years. The Hoehn-Yahr stages indicated considerable heterogeneity in the severity of PD. For example, Haas and colleagues examined both patients with relatively mild disabilities (Hoehn-Yahr stage 2) and patients with severe disabilities (Hoehn-Yahr stage 4).

**Training Protocol**

There were several differences in the WBV training protocols adopted across the 6 studies included in the review (Tab. 3). A vibrating platform was used to deliver the WBV treatment in all studies except that of King et al; they used a physioacoustic system consisting of a reclining
chair equipped with several speakers and a computer that produced sound vibrations. When study participants sat in the chair, their legs, lower back, and upper back came into contact with the surface of the chair, exposing a large part of the body to the vibrations.

In 4 studies, the immediate effects of only a single session of WBV were specifically assessed.46–48,51 In contrast, the experimental group observed by Ebersbach et al49 underwent 2 WBV sessions per day, 5 days per week for 3 weeks, and the outcomes were measured before and after the 3-week training period. Arias et al50 implemented a WBV program consisting of 12 sessions spread over a 5-week period before carrying out intrasession evaluations (ie, assessing the effects of a single session) and end-of-program evaluations (ie, assessing the effects of the 5-week program). With regard to the parameters of the vibration signals, a frequency of 6 Hz was used in 4 studies,46–48,50 and 25 Hz was used in 1 study.49 The amplitude of the signals also varied, from 3 mm46–48 to as high as 14 mm.49 King et al51 did not report the frequency or amplitude of the vibration signals generated by the physioacoustic system that they used.

Effects on Sensorimotor Performance

Motor impairments (Unified Parkinson Disease Rating Scale [UPDRS]). The motor section of the Unified Parkinson Disease Rating Scale (UPDRS) was used to assess the effects of WBV on motor impairments in 4 studies (Tab. 4).47,49–51 Haas et al47 assessed the immediate effects of a single session of WBV (five 1-minute bouts). They found that the UPDRS motor score fell significantly immediately after the treatment, whereas no significant change was observed with the control condition. Among the different symptom clusters, reductions in tremor, rigidity, and bradykinesia and

<table>
<thead>
<tr>
<th>Study</th>
<th>Level of Evidence</th>
<th>Study Design</th>
<th>Sample Size (n)</th>
<th>Age (y)</th>
<th>Sex</th>
<th>Pretest UPDRS Motor Score</th>
<th>Hoehn-Yahr Stage</th>
<th>Dosage of Levodopa (mg/d)</th>
<th>Duration of Disease (y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbinski et al46</td>
<td>2b</td>
<td>Nonrandomized controlled trial</td>
<td>52 (26 in WBV and 26 in CON)</td>
<td>69.1 (8.9)</td>
<td>14 women and 38 men</td>
<td>40.0 (11.2)</td>
<td>3 or 4</td>
<td>494 (192)</td>
<td>8.5 (0.7)</td>
</tr>
<tr>
<td>Haas et al47</td>
<td>1b</td>
<td>Randomized controlled trial with crossover</td>
<td>68</td>
<td>65.0 (7.8)</td>
<td>15 women and 53 men</td>
<td>29.9 (11.9)</td>
<td>2–4</td>
<td>325 (122)</td>
<td>5.9 (4.9)</td>
</tr>
<tr>
<td>Haas et al48</td>
<td>2b</td>
<td>Nonrandomized controlled trial</td>
<td>28 (19 in WBV and 9 in CON)</td>
<td>63.1 (7.3)</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>357 (139)</td>
<td>NR</td>
</tr>
<tr>
<td>Ebersbach et al49</td>
<td>2b</td>
<td>Randomized controlled trial</td>
<td>21 (10 in WBV and 11 in CON)</td>
<td>WBV: 72.5 (6.0)</td>
<td>CON: 75.0 (6.8)</td>
<td>14 women and 7 men</td>
<td>WBV: 23.0 (4.9)</td>
<td>CON: 25.9 (8.1)</td>
<td>NR</td>
</tr>
<tr>
<td>Arias et al50</td>
<td>2b</td>
<td>Nonrandomized controlled trial</td>
<td>21 (10 in WBV and 11 in CON)</td>
<td>WBV: 66.9 (11.1)</td>
<td>CON: 66.6 (5.6)</td>
<td>9 women and 12 men</td>
<td>WBV: 24.8 (7.1)</td>
<td>CON: 30.5 (7.1)</td>
<td>NR</td>
</tr>
<tr>
<td>King et al51</td>
<td>2b</td>
<td>Randomized controlled trial with crossover</td>
<td>40</td>
<td>65.4 (9.9)</td>
<td>15 women and 25 men</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>6.8 (4.8)</td>
</tr>
</tbody>
</table>

a UPDRS=Unified Parkinson Disease Rating Scale, WBV=whole-body vibration group, CON=control group, NR=not reported.

b Based on the PEDro scores and guidelines set by the Centre for Evidence-Based Medicine (level 1b indicated a good-quality randomized controlled trial, and level 2b indicated a poor-quality randomized controlled trial).

c Participants in all of the studies were patients with idiopathic Parkinson disease.

d Reported as mean (standard deviation).
improvements in gait and posture after WBV were found, but no reduction in cranial symptoms was observed. In a study with a crossover design, King et al.\(^5\) also assessed the immediate effects of a single session of WBV (five 1-minute bouts). Significantly greater reductions in UPDRS rigidity and tremor scores were found after WBV than after the control period. In contrast, Ebersbach et al.\(^4\) and Arias et al.\(^5\) showed that a longer-term WBV program (3–5 weeks) was not superior to conventional exercises in improving the UPDRS motor score.

**Balance.** Balance was specifically measured in several studies (Tab. 4).\(^4\),\(^6\),\(^9\),\(^5\) For example, Turbanski et al.\(^4\) and Ebersbach et al.\(^4\) both

### Table 3.
**Training Protocols**

<table>
<thead>
<tr>
<th>Study</th>
<th>Protocol for Whole-Body Vibration (WBV) Group</th>
<th>Frequency of Sessions (Duration of Program)</th>
<th>No. of Vibration Bouts (Duration/Bout)</th>
<th>Rest Between Bouts</th>
<th>Frequency (Amplitude) of Vibration Signals</th>
<th>Device</th>
<th>Posture</th>
<th>Additional Treatment</th>
<th>Protocol for Comparison Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbanski et al.(^4)</td>
<td>Single session</td>
<td>5 (1 min)</td>
<td>NR</td>
<td>6 Hz (3 mm)</td>
<td>ZEPTOR-med system (vertical)</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>Moderate walking for 15 min</td>
</tr>
<tr>
<td>Haas et al.(^7)</td>
<td>Single session</td>
<td>5 (1 min)</td>
<td>60 s</td>
<td>6 Hz (3 mm)</td>
<td>ZEPTOR-med system, Scisens (vertical)</td>
<td>Standing on the platform with knees slightly flexed</td>
<td>None</td>
<td>None</td>
<td>No specific intervention</td>
</tr>
<tr>
<td>Haas et al.(^8)</td>
<td>Single session</td>
<td>5 (1 min)</td>
<td>60 s</td>
<td>6 Hz (3 mm)</td>
<td>Srt-medical system (vertical)</td>
<td>Standing on the platform wearing shoes and with knees slightly flexed</td>
<td>None</td>
<td>None</td>
<td>Rest for 15 min</td>
</tr>
<tr>
<td>Ebersbach et al.(^9)</td>
<td>Two sessions/d for 5 d/wk (3 wk)</td>
<td>2 (15 min)</td>
<td>NR</td>
<td>25 Hz (7–14 mm)</td>
<td>Galileo (left-right alternating)</td>
<td>Standing on the platform with knees and hips slightly flexed</td>
<td>Standard therapy (3 sessions of 40-min relaxation techniques, speech therapy, occupational therapy, and release maneuvers for rigidity)</td>
<td>Standard therapy and conventional balance training (exercises on a tilt board)</td>
<td></td>
</tr>
<tr>
<td>Arias et al.(^5)</td>
<td>Total of 12 sessions on nonconsecutive days (5 wk)</td>
<td>5 (1 min)</td>
<td>60 s</td>
<td>6 Hz (NR)</td>
<td>Fit Massage (left-right alternating)</td>
<td>Standing on the platform with feet apart and knees slightly bent</td>
<td>None</td>
<td>None</td>
<td>Standing on the platform without vibration and with equal weight bearing on the 2 sides</td>
</tr>
<tr>
<td>King et al.(^1)</td>
<td>Single session</td>
<td>5 (1 min)</td>
<td>60 s</td>
<td>NR</td>
<td>Physioacoustic chair</td>
<td>Sitting in the chair with lower legs, thighs, buttocks, lower back, and upper back in contact with the surface of the chair</td>
<td>None</td>
<td>None</td>
<td>Rest</td>
</tr>
</tbody>
</table>

\(^a\) NR—not reported.
assessed the extent of postural sway in participants standing on a movable platform. In the former study, the linear displacement of the pivot of the tilt board was used as the outcome, whereas in the latter study, the sum of the displacements of the platform in the anterior-posterior and medial-lateral directions was used to obtain a quantitative body sway value.

### Table 4.
Effects of Whole-Body Vibration (WBV) Therapy on Sensorimotor Performance

<table>
<thead>
<tr>
<th>Study</th>
<th>UPDRS</th>
<th>Other Measures of Sensorimotor Performance</th>
<th>Adverse Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbanski et al⁴⁶</td>
<td>UPDRS</td>
<td>Postural sway during side-by-side standing: NS</td>
<td>NR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Postural sway during tandem standing: WBV group showed significantly more improvement than control group (P&lt;.04)</td>
<td></td>
</tr>
<tr>
<td>Haas et al⁴⁷</td>
<td>UPDRS motor score and cluster scores (tremor, rigidity, gait and posture, and bradykinesia): significant improvement after WBV (P&lt;.01) but no significant change with the control condition</td>
<td>Maximum knee angle, minimum knee angle, and movement frequency: NS</td>
<td>No adverse effects</td>
</tr>
<tr>
<td></td>
<td></td>
<td>UPDRS cranial symptom cluster score: NS</td>
<td></td>
</tr>
<tr>
<td>Haas et al⁴⁸</td>
<td></td>
<td>Proprioception performance in knee</td>
<td>No adverse effects</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maximum knee angle, minimum knee angle, and movement frequency: NS</td>
<td></td>
</tr>
<tr>
<td>Ebersbach et al⁴⁹</td>
<td>UPDRS motor score immediately after termination of the 3-wk treatment: NS</td>
<td>Immediately after termination of the 3-wk treatment: NS</td>
<td>NR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tinetti Balance Test, 10-m walk test, stand-walk-sit test, and pull test: NS</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Posturography (sway, mm): tendency for WBV group to have a lower sway value (P&lt;.093)</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>At 4wk follow-up:</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tinetti Balance Test, 10-m walk test, stand-walk-sit test, and pull test: no significant decline in performance for both WBV and control groups</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Posturography (sway, mm): tendency for WBV group to have a lower sway value (P&lt;.093)</td>
<td></td>
</tr>
<tr>
<td>Arias et al⁵⁰</td>
<td>Effects of multiple sessions</td>
<td>Effects of a single session</td>
<td>NR</td>
</tr>
<tr>
<td></td>
<td>UPDRS motor score: NS</td>
<td>Timed “Up &amp; Go” Test, Functional Reach Test, and pegboard task: NS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>UPDRS total score: NS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>King et al⁵¹,⁵²</td>
<td>Rigidity</td>
<td>Step length</td>
<td>NR</td>
</tr>
<tr>
<td></td>
<td>Group A: significant improvement after WBV (P&lt;.049); no significant change after rest period (P=.141)</td>
<td>Group A: no significant change across assessments</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Group B: significant improvement after both rest period (P=.003) and WBV (P&lt;.001)</td>
<td>Group B: postvibration value was significantly better than baseline value but differed from postrest value only slightly (P=.05)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tremor</td>
<td>Gait speed: NS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Group A: significant improvement after WBV (P&lt;.001); tremor value remained lower than baseline value after rest period (P=.021)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Group B: no significant change across assessments</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other UPDRS cluster scores: NS</td>
<td>Pegboard task</td>
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<td></td>
<td></td>
<td>Group A: significant improvement after WBV and rest period (P&lt;.008); no significant change after rest period (P&lt;.056)</td>
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<tr>
<td></td>
<td></td>
<td>Group B: significant improvement after both rest period (P&lt;.039) and WBV (P&lt;.001)</td>
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⁴⁶ UPDRS = Unified Parkinson Disease Rating Scale, NS = no significant effect compared with effect of control or conventional therapy, NR = not reported.
⁴⁷ In the study of King et al,⁵¹ treatment with WBV was followed by a rest period for group A, and a rest period was followed by treatment with WBV for group B.
experienced significantly more improvement in postural sway during tandem standing (ie, 1 foot placed in front of the other) after a single session of WBV than the control group. However, examination of their data showed that the trend in the change in postural sway observed during the treatment period was very similar to, if not less marked than, that observed during the control period. On the other hand, Ebersbach et al49 reported that the WBV group experienced significant improvement in postural sway but reported no significant change in the conventional therapy group. However, the group × time interaction did not reach statistical significance (P=.093). In addition to the aforementioned posturography tests, Ebersbach et al49 and Arias et al50 also used various clinical measures of functional balance (eg, Tinetti Balance Test, Berg Balance Scale, Functional Reach Test) to evaluate balance ability. Neither group of investigators found any difference between the WBV group and the comparison group on these functional balance measures.

Mobility tasks. The effects of WBV on mobility tasks were evaluated in 3 studies (Tab. 4).49–51 King et al51 found that a brief WBV session had no significant effect on gait speed. Their findings for step length were also inconsistent. Participants in group A, the first to receive WBV, experienced no significant change in step length after WBV. Intriguingly, participants in group B, who received WBV after the rest period, experienced a significant increase in step length.51 When WBV was compared with conventional therapy, none of the mobility parameters (ie, the Timed “Up & Go” Test, a 10-m walk test, and a stand-walk-sit test) measured by Ebersbach et al49 and Arias et al50 showed any significant treatment effect after multiple sessions of WBV.

Table 5. Summary of Main Findingsa

<table>
<thead>
<tr>
<th>Effects of Whole-Body Vibration (WBV)</th>
<th>Findings</th>
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<tbody>
<tr>
<td>Acute (single session)</td>
<td>In 2 studies (level 1b and level 2b), significant results for UPDRS tremor and rigidity scores favored WBV over no intervention</td>
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<tr>
<td></td>
<td>Conflicting results for UPDRS gait and posture, bradykinesia, and cranial symptom cluster scores</td>
</tr>
<tr>
<td>Chronic (multiple sessions over 3–5 wk)</td>
<td>No evidence that WBV is effective in improving knee proprioception and other clinical measures of sensorimotor performance (such as balance and mobility)</td>
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<tr>
<td></td>
<td>Two level 2b studies showed that, compared with conventional exercises, WBV had no significant effect on UPDRS motor scores</td>
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<tr>
<td></td>
<td>Only 1 level 2b study showed that, compared with conventional exercises, WBV had a tendency to improve performance on dynamic posturography tests but not on other clinical measures of gait and balance</td>
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</table>

a The overall conclusion was that none of the studied outcomes provided adequate evidence to support the use of WBV as the current “best practice” for PD. UPDRS–Unified Parkinson Disease Rating Scale.

**Proprioception.** The effects of WBV on sensory functioning were assessed in only 1 study (Tab. 4).48 Haas et al48 assessed the proprioceptive function of the knee joint by asking participants to reproduce a slowly oscillating target course (0.25 Hz, amplitude: ±10°) involving unilateral, repetitive knee extension and flexion movements. The average maximum and minimum knee angles of the movement series were used as the outcome measures to represent the quality of proprioception. In addition, they analyzed knee joint movement velocity to indicate timing deficits. No significant changes in these variables after a single session of WBV were found.48

**Pegboard task.** Arias et al50 used the Purdue Pegboard Test to assess manual dexterity; the mean number of pegs introduced into the holes was used as the outcome measure (Tab. 4). No significant treatment effect was reported. On the other hand, King et al51 used a timed pegboard task to assess bradykinesia. Participants were required to place the pegs into the holes with randomly positioned slots as quickly as they could. For one of the treatment groups, the improvement in performance on this pegboard task after the control period was very similar to that observed after the WBV treatment period that followed. It thus was difficult to determine whether the change in performance was due to the practice effect or maturation or was attributable to an effect of the vibration treatment.

**Adverse Events**
Haas and colleagues47,48 explicitly stated that no adverse effects were associated with WBV, whereas none of the other studies reported on whether any adverse events occurred during or after WBV treatment.

**Discussion**

**Training Protocol**
There were great variations in the training protocols adopted in the selected studies. Although a vibrating platform was used to deliver the WBV treatment in most of the stud-
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ies,46–50 King et al51 used a physioacoustic system. A similar system was used in a recent study by Zheng et al,52 who found that a 6-month vibration treatment program was effective in improving mobility and reducing bone turnover in a group of older adults who were frail. This system may be more suitable for people who have more severe disabilities and cannot tolerate standing on a vibrating platform. In addition, a physioacoustic system may allow for more uniform delivery of stimulation to the body than is possible with a vibrating platform because a large part of the body surface is in contact with the chair. Although it has been claimed that the sound waves created by the physioacoustic system are physically similar to mechanical vibration,52 whether they produce the same physiological effects remains uncertain.

Effects of a Single Session of WBV

The immediate effects of a single session of WBV in people with PD (ie, acute effects) were investigated in 5 studies.46–48,50,51 The results were mixed. There was no evidence to suggest that WBV can improve performance in proprioception.46 Significantly better outcomes with WBV than with no intervention, as reflected in UPDRS tremor and rigidity scores, were reported by Haas et al47 (level 1b) and King et al51 (level 2b); however, the methods that they used to deliver vibration were different (vibrating platform versus physioacoustic chair). The results on other UPDRS subscales were conflicting.47,50,51 Arias et al50 showed that participants in the WBV group recorded gains in sensorimotor performance (eg, Functional Reach Test, Timed “Up & Go” Test) similar to those experienced by participants in the placebo group (who performed the same exercises without vibration). Therefore, the possibility that the beneficial effects of WBV observed by Haas et al47 and King et al51 were related to a placebo effect associated with this form of treatment cannot be ruled out. Studies on the acute effects of WBV in young adults53–56 and patients with chronic neurological conditions23,27,28 also have produced conflicting results. The discrepancies in the reported outcomes presumably are related to differences in participant characteristics, WBV protocols, and outcome measures.

The mechanisms underlying the reported improvements in postural sway and the UPDRS motor score in people with PD are not clear.46–47 It is likely that several physiological systems are involved because earlier studies conducted with other populations demonstrated the influence of WBV on neuromuscular,18–22 vascular,57 and hormonal58 systems. For example, it is known that WBV can affect the concentrations of several neurotransmitters.53,58,59 The possibility that WBV has an effect on the dopaminergic system that may contribute to the observed improvement in neuromuscular performance cannot be ruled out. Some form of neuropsychiatric change also may be involved because it has been shown that focal muscle vibration can induce long-lasting plastic changes in the motor cortex.60 Increased neuromuscular efficiency may account for these improvements. It has been proposed that WBV may enhance the activity of agonist muscles but inhibit that of antagonist muscles, thus leading to the optimal coordination of muscle synergy.24,61

In summary, evidence of the acute effects of WBV on sensorimotor performance remains inconclusive (Tab. 5). Given the conflicting results of and the methodological flaws in the studies reviewed here, only a grade D recommendation (ie, inconsistent evidence at any level) can be given for the use of a brief session of WBV to improve sensorimotor performance in people with PD.

Effects of Multiple Sessions of WBV

Both Ebersbach et al49 and Arias et al50 (both level 2b) investigated the effects of multiple sessions of WBV on the UPDRS scores and other aspects of sensorimotor performance (ie, chronic effects). In contrast to a larger number of WBV studies conducted with older populations and demonstrating the positive effects of longer-term WBV on balance performance and leg muscle strength,6,15–21 neither study provided sufficient evidence that WBV treatment is more effective than standard balance training49 or control exercises without vibration.50 It is possible that the differences in the WBV protocols used in these studies partially accounted for these discrepancies in the results. For example, the duration of training in most of the studies carried out with older adults was between 6 weeks and 1 year, longer than the treatment periods used by Ebersbach et al49 and Arias et al50 (3 and 5 weeks, respectively). Patients with disabilities may require longer, more intense training programs to obtain optimal treatment effects; such a requirement would explain why WBV (for 6–8 weeks) also failed to have significant effects in patients with other types of neurological conditions (eg, stroke, cerebral palsy).22,25 Moreover, both of the aforementioned studies had small samples (21 patients) (Tab. 2),49,50 and the resulting reduced statistical power rendered the detection of any significant between-group differences in treatment outcomes difficult.

In summary, only 2 fair-quality studies49,50 examined the effects of longer-term WBV; neither study showed any significant results for WBV in comparison with conven-
tional exercises, except that there was a tendency for the WBV group to show more improvements on posturography tests, as reported by Ebersbach et al.49 (Tab. 5). In view of the lack of good-quality studies and the inconsistent findings, only a grade D recommendation can be given for the use of longer-term WBV to improve sensorimotor performance in people with PD.

How does the evidence for WBV compare with that for other physical therapy interventions in people with PD? Keus et al.40 performed an evidence-based analysis of physical therapy in people with PD and made several specific treatment recommendations based on evidence from more than 2 moderate-quality controlled trials (grade B recommendation); these recommendations included the use of cueing strategies (eg, auditory, visual, tactile, cognitive) to improve walking, the application of cognitive movement strategies to improve the performance of transfers, the use of balance training combined with lower-limb strength training to improve balance, and the use of flexibility and resistance exercises designed to improve joint mobility and muscle power. Overall, research evidence supporting the use of WBV to improve sensorimotor function in people with PD is not as well established as evidence of the benefits of other common physical therapy interventions.

Safety and Adverse Events
Safety must be taken into consideration because earlier studies showed that occupational exposure to WBV is related to vestibular problems,62 circulation disorders,65 and low back pain.64 The peak vertical acceleration of the vibration platform depends upon the following theoretical relationship: peak acceleration = 4π² × frequency squared × amplitude.65 At certain stimulation frequencies and amplitudes, vibrations may be amplified as they are transmitted through the body.65 For example, vibration (10–20 Hz) with a peak acceleration of 1g (1 unit of gravity, earth’s gravitational constant) at the level of the vibration platform could be amplified to more than 2g to 3g at the hip if the amplitude were greater than 0.5 mm.65

The use of a high-amplitude protocol for people with a very low bone mass may be hazardous because the applied load may be too great for fragile bone tissue to withstand.65 Thus, it is critical that the WBV protocol (signal frequency, amplitude, and duration of exposure) be selected carefully and reported clearly because osteoporosis is prevalent in patients with PD.66

The protocols used in each of the studies considered in this review varied. On the basis of the aforementioned theoretical relationship, the protocol adopted by Ebersbach et al.49 (25 Hz, 7–14 mm) would yield peak accelerations ranging from 17.6g to 35.2g. Although the signal would be attenuated as the vibration is transmitted through the body,65 the possibility of signal amplification associated with the use of high-amplitude vibration raises some concerns.

No significant adverse effects were reported in any of the selected studies. Earlier studies carried out with older populations15–22 and people with different chronic conditions23–30 showed that it is rare for adverse events to be associated with WBV therapy. The reported side effects are mainly limited to muscle soreness, headaches, knee pain, and joint effusion.15–22 If present, these side effects usually subside as training progresses. It seems reasonable to suggest that brief daily exposure to WBV is feasible and safe for people with PD, but further study is needed.

Limitations of the Selected Studies
Good-quality experimental studies are lacking in this area of research. In addition, because 3 of the studies selected for review were conducted by the same group of investigators and 2 of these studies had unmasked assessors,46–48 their results must be interpreted with caution. Finally, several of the selected studies had reduced statistical power because of their small samples, which also were quite heterogeneous. All of these factors may partially explain the nonsignificant findings.

Limitations of the Systematic Review
The dramatically different treatment protocols and outcome measures used in the studies reviewed here make direct comparison of their results difficult. These differences also partially explain why a meta-analysis could not be performed. The exclusion of articles written in other languages may have led to bias in the results of this review. For example, we cannot rule out the possibility that publications in other languages may have obtained results markedly different from those reported in the articles that we reviewed.

Implications for Clinical Practice
This review revealed conflicting results concerning the effects of a single session of WBV (acute effects). Two studies (a level 1b study and a level 2b study) showed that a single session of WBV had positive effects on tremor and rigidity,47,51 but these results could have been due to the placebo effect.49,50 The effects of longer-term WBV (up to 3–5 weeks) were investigated in only 2 level 2b studies, and the results were unremarkable.49,50 Overall, there is insufficient evidence to prove or refute the effectiveness of WBV in improving sensorimotor function in people with PD.
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Implications for Research

Many research questions concerning the use of WBV in people with PD remain unanswered. First, more good-quality studies are needed to determine the acute and chronic effects of various WBV protocols on sensorimotor performance in people with PD. Second, future studies should consider incorporating bone health outcomes (eg, bone density, bone turnover) because WBV has been shown to have a positive influence on hip bone density in older women. Third, whether the benefits of WBV, if any, are maintained after the termination of treatment remains to be determined. It also is important to establish the neurophysiological mechanisms underlying the sensorimotor improvements observed after WBV.

All authors provided concept/idea/research design and data analysis. Mr Lau, Ms Teo, Dr Chung, and Dr Pang provided writing. Mr Lau, Ms Teo, and Mr Yu provided data collection. Dr Pang provided project management and consultation (including review of manuscript before submission).

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