Vibration Training: Application within Phase IV Cardiac Rehab

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History

- Discovery of vibration training in Germany
- Vibration training knowledge starts to spread after fall of Berlin Wall
- Guus van der Meer introduces Power Plate on the Dutch market
- First vibration device invented by John H. Kellogg
- Russians use vibration training in their space program
- Dutch Olympic trainer Guus van der Meer develops Power Plate
- Power Plate is a worldwide success represented in over 100 countries worldwide
Characteristics of Power Plate vibrations

- Vertical vibration
  - In alignment with gravity and gravity receptor

- Multi-dimensional
  - Multi-dimensional function

Direction of the vibration:
- up and down
- forward and backward
- side to side
**Frequency of the vibration**
The number of times per seconds that the Power Plate moves up and down. Frequency is expressed in Hz (25Hz, 30 Hz, 35 Hz, 40 Hz or 50 Hz)

**Amplitude**
Distance the Power Plate displaces, per cycle, expressed in mm. (LOW - ~1mm, HIGH - ~2mm)
Application of more G-Force – Acceleration training

Force = 1.44G

(University of Toronto)
### Application of more G-Force – Acceleration training

**Acceleration measured by the University of Leuven**

<table>
<thead>
<tr>
<th>Amplitude (mm)</th>
<th>Frequency (Hz)</th>
<th>Gravity Force (g)</th>
<th>Acceleration (m/s²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>30</td>
<td>1.83</td>
<td>18.00 m/s²</td>
</tr>
<tr>
<td></td>
<td>35</td>
<td>2.32</td>
<td>22.80 m/s²</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>2.76</td>
<td>27.10 m/s²</td>
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<tr>
<td></td>
<td>50</td>
<td>3.48</td>
<td>34.10 m/s²</td>
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<tr>
<td>High</td>
<td>30</td>
<td>3.17</td>
<td>31.10 m/s²</td>
</tr>
<tr>
<td></td>
<td>35</td>
<td>3.99</td>
<td>39.10 m/s²</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>5.11</td>
<td>50.09 m/s²</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>6.36</td>
<td>62.40 m/s²</td>
</tr>
</tbody>
</table>
Myotatic Stretch Reflex

Classical reflex arc

Afferent side
sensory

Receptor
Neuromuscular spindle

Effector
Muscle-contraction

Efferent side
motor

Neuromuscular spindle = measures change in length and rate of change in length

reflex = unconscious and fast

Spinal cord
“**Tonic vibration reflex** is a sustained contraction of a muscle subjected to vibration. This reflex is caused by vibratory activation of muscle spindles — muscle receptors sensitive to stretch.

Tonic vibration reflex activates receptors of the skin, tendons and, most importantly, muscle spindles. Muscle spindle discharges are sent to the spinal cord through afferent nerve fibers, where they activate monosynaptic and polysynaptic reflex arcs, causing the muscle to contract.”

*Wikipedia, 2009*

- TVR discovered by Hagbarth and Eklund, 1966
Power Plate is officially classified as a class IIa Medical Device within the European Economic Area (EEA). This has been achieved under the Medical Devices Directive (MDD) 93/42/EEC as amended.

The following medical claims have been investigated and officially upheld:

- Can assist in falls prevention
- Enhancement of strength and power
- Reduction / alleviation of chronic pain
- Reduction in appearance of cellulite
- Body weight and body fat reduction
- Enhancement of bone density and prevention of bone mineral loss
- Enhancement of circulation and functioning of cardiovascular system
- Enhancement of flexibility and range of motion
Title: Whole-body-vibration-induced increase in leg muscle activity during different squat exercises.

Authors: Roelants M, Verschueren S, Delecluse C, Levin O, Stijnen V.

Published: Journal of Strength and Conditioning Research, 2006

Location: University of Leuven, Belgium.

Duration: 1 day

Subjects: 15 male physical education students (mean age 21.2 years)

Power Plate: Next Generation
Protocol:

- 1 groups, 2 conditions:
  - Power Plate condition
  - Control condition

- Power Plate condition:
  - EMG recordings of the rectus femoris, vastus lateralis, vastus medialis and gastrocnemius.
  - 20s, 35 Hz and 2.5mm amplitude vibration
  - 4 sets of 3 exercises (squat, deep squat and one legged squat)
  - 1 min rest in between each set and exercise.

- Control condition:
  - Same as Power Plate condition but without the vibration.
Results:

- **Rectus femoris muscle**

- **Vastus medialis muscle**

- **Vastus lateralis muscle**

- **Gastrocnemius muscle**

*Significant difference*
Conclusions:
• “in all 3 exercises WBV elicits a significant increase in leg muscle activity compared with the same exercises without WBV.”

Discussion:
• The EMG signal was higher in the muscles closer to the platform. So the vibration effect was clearly dependent on the distance between the muscle and the vibration platform.
• During WBV, activation of the leg muscles varied between 12.6 and 82.4% of values recorded during an isolated MVC of that muscle.
Title: Strength increase after Whole Body Vibration compared with resistance training

Authors: Delecluse C, Roelants M, Verschueren S.

Published: Medicine & Science in Sports & Exercise, 2003.

Location: University of Leuven, Belgium.

Duration: 12 weeks

Subjects: 74 young female adults (mean age 21.5 years)

Power Plate: Classic
Protocol:

- 4 groups:
  - Power Plate training group (PP)
  - Resistance training group (RES)
  - Control group (CON)
  - Placebo group (PLA)

- Training 3 times a week for 12 weeks

- Progressive training program
  - PP program: duration vibration session ↑, number of series ↑, number of different exercises ↑, rest periods ↓, amplitude and/or frequency ↑
  - RES program: 2x20RM → 2x10RM
  - PLA program: see PP program only with a vibration too subtle to elicit a training effect (< 1g)

- Power Plate exercises: Squat, deep squat, wide stance squat, one legged squat and lunge.

- Resistance training: 20 min cardiovascular, resistance training on a leg extension and leg press.
• Measurements at baseline and after 12 weeks:
  • isometric and dynamic of the knee extensors
  • explosive strength by means of a CMJ

Results:

![Graph showing improvement in knee extensors strength and power](Image)

- **Isometric strength**: 16.6% increase in Power Plate, 14.4% increase in Resistance.
- **Dynamic strength**: 9% increase in Power Plate, 7% increase in Resistance.
- **Explosive strength**: 7.6% increase in Power Plate, 0% increase in Resistance.

* * sig. difference over 12 weeks
Conclusions:

• The Power Plate increases strength at least as effectively as conventional resistance training
• Only the Power Plate training shows a significance increase in explosive strength (vertical jump height).
• Proof that Power Plates strength increases are not due to the placebo effect

Relevance:

• Power Plate training provides all the benefits of strength and power training, without the dangers of heavy loading, which makes it accessible for every person.
• The dynamics of the vibrations are very important to obtain the results that have been found in this study (Power Plate vs. Placebo group)
• The strength gain is mainly due to the vibration stimulus and not only to the unloaded exercises performed on the Power Plate.
“Long term maintenance of physical activity and lifestyle change.”

“Exercise training is a core element of cardiac rehabilitation and should be offered at least twice a week for a minimum of 8 weeks.”

“Low to moderate risk cardiac patients can undertake resistance training.”  

SIGN Guideline No. 57, 2002
Impact upon blood pressure & HR (1)

**Title:** Acute effects of exhaustive vibration exercise.

**Authors:** J. Rittweger et al.

**Published:** Clinical Physiology, 2000

**Subjects:** 37 Young healthy subjects.

**Protocol:** 2 bouts of WBV dynamic squatting (26Hz, 10.5mm amplitude, 15g) with 35-50% BW additional load, to exhaustion.

  Compared with bicycle ergometry of similar RPE.
Impact upon blood pressure & HR (1) – cont’d

**Increase in HR due to Intervention (BPM)**

- BIC
- WBV1
- WBV2
Increase in SBP due to intervention

- BIC
- WBV1
- WBV2
Impact upon blood pressure & HR (1) – cont’d

Decrease in DBP due to intervention

- BIC
- WBV1
- WBV2
Conclusions:

“The present investigation has shown that, even if performed to exhaustion, cardiovascular effects of WBV are mild.”

“All parameters returned to normal values within 15 min of recovery.”

“In consequence, the risk expected when WBV is applied in the elderly is negligible.”
Title: Controlled Whole Body Vibration to Decrease Fall Risk and Improve Health-Related Quality of Life of Nursing Home Residents

Authors: Bruyere, O. et. al.

Published: Arch Phys Med Rehabil., 2005

Subjects: 42 elderly volunteers. Nursing home residents.

Protocol: Six-week vibration intervention (3x/wk, 4 sets of 1min @ 10Hz, 3mm & 27Hz, 7mm. Standing) plus physical therapy (PT) or PT alone.

Results and Conclusions: “Changes in blood pressure and heart beat during the sessions were clinically insignificant.”

“Mean pulse was 69 beats/min and mean blood pressure was 135/76mmHg before training. The maximum changes recorded during training were an increase in pulse to 73 beats/min and a decrease in blood pressure to 129/73mmHg.”
Title: Vastus lateralis oxygenation and blood volume measured by near-infrared spectroscopy during whole body vibration

Authors: Yamada, E. et. al.

Published: Clin Physiol Funct Imaging, 2005

Subjects: 18 young healthy males.

Protocol: 180sec sets dynamic squatting on platform at 15Hz, 5mm vs. control

Results and Conclusions:

“There was no difference between changes in systolic and diastolic blood pressure with and without vibration.”

“Heart rate with vibration at only 30 s after squatting exercise was higher than that without vibration (P<0.05)” (Although there was a trend towards higher heart rate with vibration).
Impact upon blood pressure & HR (3) – Blood Pressure

**Figure 4** Changes in blood pressure (mean ± SD) during squat exercise with and without vibration and recovery.
Figure 3 Changes in heart rate (mean ± SD) during squat exercise with and without vibration and recovery. *, statistically significant difference (P<0.05, Student’s paired t-test) from those at the same time with vibration.
Title: ‘Whole-body vibration exercise leads to alterations in muscle blood flow.’

Authors: K. Kerschan-Schindl et al.

Published: Clinical Physiology, 2001

Subjects: 20 healthy adults (8 females, 12 males).

Participants were physically active but did not engage in strength or strenuous power training

Protocol: 3 sets of WBV static squatting (26Hz, 3mm amplitude) at different squat depths for 3mins per set.

Results:

“Heart rate values, systolic and diastolic blood pressures after exercise did not show a statistically significant change compared with baseline.”

“Muscular blood circulation in the calf and thigh significantly increased after exercise.”

“Mean blood flow velocity in the popliteal artery increased from 6.5 to 13.0 cm s-1 and its resistive index was significantly reduced.”
Impact upon blood pressure and muscle blood volume – Cont’d

Results cont’d:

Muscle blood circulation in calf and thigh
Conclusions:

“The results indicate that low-frequency vibration does not have the negative effects on peripheral circulation known from occupational high-frequency vibration.”

“...this supposed muscular exercise did not alter the heart rate or blood pressure.”

“These findings are in line with Rittweger et al. (2000) who reported that, even if performed to exhaustion, cardiovascular effects of vibration exercise are mild.”
Impact upon Total Peripheral Resistance and blood pressure

**Title:** Vibration training: benefits and risks

**Authors:** Mester, J. et. al.

**Published:** Journal of Biomechanics, 2006

**Subjects:** 1 healthy man (43) and 1 healthy woman (24)

**Protocol:** 6, 30s sets standing on platform at 30Hz, 40Hz & 50Hz and at 2mm & 4mm.

**Results and Conclusions:**

"Except the last vibration test (50 Hz, 4 mm), TPR increased considerably for both subjects during vibrations compared with before the test."

"After the vibration tests, TPR dropped to a value which was even considerably lower than before the tests for both subjects."
Impact upon Total Peripheral Resistance and blood pressure – Cont’d

Results and Conclusions cont’d:

“The mean blood pressure increased during vibration for both subjects.”

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![Graphs showing changes in mean blood pressure](image-url)
Results and Conclusions cont’d:

“During body vibrations the external pressures acting on the walls of the blood vessels will not be isotropic. Therefore, the vessels will deform. Namely, the cross section of the vessel will not remain round, but change to a more or less elliptic shape.”

“...resistance of a tube with elliptic cross section to the flow is larger than the resistance of a round tube with the same circumference.”

“Thus, the increased resistance to the blood flow caused by the deformation of vessels, particularly the small vessels, during body vibration gives an explanation of the increased TPR during body vibration.”

“The exposure duration for each vibration training should be very short (20-60s).”

“Vibration training should be avoided for the people who have existing coronary disease or hypertension.”
Impact upon catecholamines

Title: Effects of whole-body vibration exercise on the endocrine system of healthy men

Authors: Di Loreto, C. et. al.

Published: J. Endocrinol. Invest. 2004

Subjects: 10 healthy males.

Protocol: 25mins standing on platform at 20Hz vs. control

Results and Conclusions: There were no significant differences between the vibration and the control groups in terms of plasma HGH, IGF-1, testosterone and epinephrine levels.

However, “In the vibration study, plasma concentration of norepinephrine at 60 min was higher than the 60 min control level (p=0.038).”

N.B. But no significant difference immediately following exercise.
Impact upon catecholamines – Cont’d

Change in plasma norepinephrine from baseline to 35 mins post exercise (nM)
Pulse Wave Velocity

“Arterial stiffness is a major cause of cardiovascular disease. Increases in arterial stiffness increase central systolic & pulse pressure, and demand on the left ventricle, and decrease the perfusion pressure through the coronary arteries, thereby increasing the risk of heart attacks, heart failure and stroke.

Pulse wave velocity is a well-established technique for obtaining a measure of arterial stiffness between two locations in the arterial tree. The velocity of the pulse wave along an artery is dependent on the stiffness of that artery.”

http://www.atcormedical.com
Title: Arterial stiffness acutely decreases after whole-body vibration in humans
Authors: Otsuki, T. et. al.
Published: Acta Physiol., 2008
Subjects: 10 healthy men.
Protocol: 10 sets of static squatting with vibration (26 Hz) for 60 s vs. Control
Results and Conclusions: “Heart rate and blood pressure did not change from baseline after both trials.”
“baPWV (brachial-ankle pulse wave velocity) did not change in the CON trial”
However “baPWV decreased 20 and 40 min after the WBV trial and recovered to baseline 60 min after the trial.”
“These results suggest that WBV acutely decreases arterial stiffness.”
Title: The acute and chronic effects of WBV on autonomic and hemodynamic cardiovascular function in overweight-obese individuals with prehypertension.

Authors: Figueroa, A. et. al.

Published: Pre-submission, 2009 (Florida State University)

Subjects: 9 college aged (18-35 years) individuals exhibiting pre-hypertension vs. Control

Protocol: Static squat position at 120 degrees and/or using different exercises and postures at a fixed frequency 40Hz and amplitude (LOW – 2mm) on a Power Plate machine – 10sets.

Results and Conclusions:

“These results seem to suggest that vibration exercise is not risky and should not be contraindicated in hypertensive populations.”

“The LF/HF ratio is a commonly used marker of sympathetic activity. The higher the ratio means increase sympathetic activity. Interestingly static exercise and WBV exercise increased the ratio; however it was not different between the sessions. This data seems to suggest that WBV is not more risky than static exercise alone.”
Results and Conclusions cont’d:

“Both static squat (non-WBV) and (with) WBV reduce leg arterial stiffness, however the WBV has a longer lasting effect evident at 30 minutes post exercise. All together (this) is promising to cardiac patients since it basically tells that WBV might be used to alter and improve vascular function in a beneficial way without the risks that are experienced in other types of exercise.”

![Leg Pulse Wave Velocity vs time graph](image)
Title: Short-term effects of whole-body vibration on postural control in unilateral chronic stroke patients: preliminary evidence.

Authors: van Ness, I. et. al.

Published: Am J Phys Med Rehabil. 2004

Subjects: 23 chronic stroke patients.

Protocol: 4 x 45sec sets shallow squatting on platform at 30Hz, 3mm

Relevant results and Conclusions:

“All patients were able to tolerate the selected 30-Hz frequency already during the first administration of WBV. No administration of WBV had to be aborted due to immediate adverse effects nor did patients mention any subjective complaints after the vibration.”

“The finding that no adverse effects occurred and that nearly all patients reported pleasant subjective sensations both during and after the vibration therapy suggests that WBV may also be a safe application of SSS (Somato-sensory stimulation) in (chronic) stroke patients. This latter conclusion is further supported by our experiences with postacute stroke patients included in an ongoing randomized, controlled trial investigating the effects of prolonged vibration therapy (daily during 6 wks) on postural control.”
Title: Long-Term Effects of 6-Week Whole-Body Vibration on Balance Recovery and Activities of Daily Living in the Post-acute Phase of Stroke: A Randomized, Controlled Trial

Authors: van Ness, I. et. al.

Published: Stroke, 2006

Subjects: 53 patients with moderate to severe functional disabilities were randomized within 6 weeks post-stroke and within 3 days after admission to a rehabilitation center

Protocol: 445 secs (total) shallow squatting on platform (30Hz, 3mm) 5x/wk for 6wks vs. control (Exercise to music therapy group)

Relevant results and Conclusions:

“...this treatment was well tolerated and appreciated by most patients.”
Title: Safety of Whole Body Vibration Exercise for Heart Transplant recipients

Authors: Crevenna, R. et. al.


Subjects: 14 male clinically stable heart transplant recipients.

Protocol: Single set of squats to exhaustion (mean 248s).

Results and Conclusions: “No patient experienced adverse effects.”

“...WBV is feasible and safe in heart transplant recipients.”

“Heart rate, systolic and diastolic blood pressure, lactate levels and Borg scale increased significantly during WBV, but did not reach higher levels than those achieved during aerobic exercise.”
Table 2  Mean and standard deviations of the investigated parameters (n = 14)

<table>
<thead>
<tr>
<th></th>
<th>baseline</th>
<th>exhaustion</th>
<th>recovery 3 minutes</th>
<th>recovery 5 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasma lactate (mM/L)</td>
<td>1.2 ± 0.3</td>
<td>2.0 ± 1.6*</td>
<td>2.3 ± 0.8*</td>
<td>2.1 ± 0.7*</td>
</tr>
<tr>
<td>Heart rate (beats per minute)</td>
<td>98 ± 10</td>
<td>121 ± 20*</td>
<td>107 ± 15</td>
<td>104 ± 14</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>136 ± 17</td>
<td>158 ± 23*</td>
<td>139 ± 15</td>
<td>139 ± 15</td>
</tr>
<tr>
<td>Diastolic blood pressure (mmHg)</td>
<td>90 ± 13</td>
<td>93 ± 16</td>
<td>93 ± 13</td>
<td>91 ± 13</td>
</tr>
</tbody>
</table>

*p < 0.05, Wilcoxon sign rank test
**Blood Pressure:** Increases in SBP during exercise would appear to be insignificant to mild and less dramatic than those experienced in conventional CV exercise. Similarly, decreases in DBP would appear to be greater than with conventional exercise methods. Furthermore, BP returns to normal relatively quickly (<15mins) following exercise.

Only one paper showed a significant, negative effect and this was only carried out on two subjects (Mester et. al., 2006)

**HR:** Increases in HR during exercise would appear to be no greater than those than those experienced in conventional CV exercise and in many cases appear to be significantly lower.

**TPR:** Mester et. al., (2006) suggested that WBV increased TPR during exercise, yet TPR dropped following exercise. This study was, however, only carried out on two subjects.

**Arterial Stiffness:** WBV would appear to decrease arterial stiffness for a significant period (up to 40mins) following exercise.
Catecholamine release: Although in one specific case there was some indication that norepinephrine may increase following WBV exercise, generally speaking there was little effect upon catecholamine release.

Safety in persons post-stroke and post-heart transplant as well as those with pre-hypertension:
Considering the information presented here it would appear as if WBV is a safe exercise intervention in individuals recovering from stroke and heart transplant, as well as for those with pre-hypertension.
Thank you.