Auszwirkungen eines Power Plate-Trainings im Vergleich zu einem konventionellen Fitnesstraining auf Muskelkraft und Muskelmasse bei älteren Männern: Eine kontrollierte und randomisierte 1-Jahres-Studie


Ziel der Studie:
Untersuchung ob ein Power Plate-Training eine zeitsparende Alternative zur Verbesserung von Muskelkraft und Muskelmasse durch ein klassisches Fitnessprogramm bei älteren Männern darstellt.

Methoden:
Diese 12-monatige Studie wurde mit 97 Senioren (Alter 60-80 Jahre) durchgeführt. Die Probanden wurden in folgende Versuchsgruppen aufgeteilt:

1. Power Plate-Gruppe (PP): 3 mal/Woche, 30 – 40 Hz, low- und high-Amplitude

Als Untersuchungsparameter wurden die isometrische Kraft (Dynamometer), Explosivkraft (Sprungkraft) und die Muskelmasse (Computertomographie) gemessen.

Ergebnisse:

Fazit:
Die Studie zeigt, dass ein Power Plate-Training bei männlichen Senioren genauso effizient wie ein klassisches Fitnessprogramm ist, wenn es um die Steigerung der isometrischen und explosiv-dynamischen Kraftfähigkeiten der unteren Extremitäten, sowie um den Muskelauflauf geht. Das Power Plate-Training ist demnach eine wirkungsvolle Möglichkeit, dem altersbedingten Verlust an Muskelmasse und der damit verbundenen Reduktion der Leistungsfähigkeit zeitsparend und nebenwirkungsfrei entgegenzuwirken.
Impact of Whole-Body Vibration Training Versus Fitness Training on Muscle Strength and Muscle Mass in Older Men: A 1-Year Randomized Controlled Trial

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Background. This randomized controlled study investigated the effects of 1-year whole-body vibration (WBV) training on isometric and explosive muscle strength and muscle mass in community-dwelling men older than 60 years.

Methods. Muscle characteristics of the WBV group (n = 31, 67.3 ± 0.7 years) were compared with those of a fitness (FIT) group (n = 30, 67.4 ± 0.8 years) and a control (CON) group (n = 36, 68.6 ± 0.9 years). Isometric strength of the knee extensors was measured using an isokinetic dynamometer, explosive muscle strength was assessed using a counter movement jump, and muscle mass of the upper leg was determined by computed tomography.

Results. Isometric muscle strength, explosive muscle strength, and muscle mass increased significantly in the WBV group (9.8%, 10.9%, and 3.4%, respectively) and in the FIT group (13.1%, 9.8%, and 3.8%, respectively) with the training effects not significantly different between the groups. No significant changes in any parameter were found in the CON group.

Conclusion. WBV training is as efficient as a fitness program to increase isometric and explosive knee extension strength and muscle mass of the upper leg in community-dwelling older men. These findings suggest that WBV training has potential to prevent or reverse the age-related loss in skeletal muscle mass, referred to as sarcopenia.
(i) diseases or medications known to affect bone metabolism or muscle strength and (ii) engagement in moderate-intensity exercise programs for >2 hours/week. After a medical screening including a graded maximal bicycle test where heart rate was recorded continuously, 220 men (n = 114) and women (n = 106) were randomly assigned to one of three groups: the WBV group, fitness (FIT) group, or control (CON) group. All participants were enrolled in a 1-year randomized controlled study on the effects of training on health-related parameters. Muscle mass was only measured in a subset of 97 men. The main focus of this article is comparison, isometric strength data of the 106 female participants (WBV: n = 46, FIT: n = 30, and CON: n = 36). For comparison, isometric strength data of the 106 female participants (WBV: n = 46, FIT: n = 30, and CON: n = 30) are described briefly at the end of the Results section.

The study was approved by the University’s Human Ethics Committee according to the declaration of Helsinki. All participants gave written informed consent.

**Interventions**

The WBV and FIT groups trained three times weekly for 1 year, with at least 1 day of rest between the training sessions. All sessions were held at the University Training Center and were closely supervised by qualified health and fitness instructors.

**WBV Group**

The WBV group exercised for a maximum of 40 minutes on a vibration platform (Powerplate, Amsterdam, The Netherlands): squat, deep squat, wide stance squat, toes-stand, toes-stand deep, one-legged squat, and lunge. Training load increased gradually according to the overload principle (Table 1).

**FIT Group**

The FIT group performed cardiovascular, resistance, balance, and flexibility exercises for about 1.5 hours in total. The guidelines of the American College of Sports Medicine for exercise prescription in older individuals were used to set up the intensity of the program (19). The cardiovascular program (70%–85% of the heart rate reserve) consisted of walking/running, cycling, or stepping. The resistance program (1–2 sets with a load between 8 and 15 repetition maximum) consisted of exercises for the whole body, including leg press and leg extension (Technogym Systems, Gambetolla, Italy). Balance was trained by standing on one or both legs with the eyes open or closed, on a firm or unstable surface. At the end of each session, the participants performed stretching exercises.

**CON Group**

The CON group was repeatedly advised not to change lifestyle or physical activity during the project. The Flemish Physical Activity Computerized Questionnaire (FPACQ) determining lifestyle and activity patterns, showed no significant changes in physical activity level in the CON group during the study (p = .909).

**Outcome Measurements**

Isometric and explosive strength of the quadriceps muscle and muscle mass of the upper leg were evaluated at baseline and after 12 months.

**Isometric strength.**—Isometric knee extension strength was tested on an isokinetic dynamometer (Biodex; Shirley, NY) (20) on the right side, unless there was a medical problem. The rotational axis of the dynamometer was aligned with the transversal knee-joint axis and connected to the distal end of the tibia using a lever arm. The highest torque (Nm) of two maximal contractions (with a knee joint angle of 120°) was further analyzed.

**Explosive strength.**—A counter movement jump (21) was performed on a contact mat to evaluate the explosive capacity of the lower limb muscles after a stretch-shortening cycle. We analyzed the average jump height (in centimeters) of three separate jumps.

### Table 1. Characteristics of the Whole-Body Vibration Training Program

<table>
<thead>
<tr>
<th>Period (Week)</th>
<th>Volume Duration of exercise (s)</th>
<th>Frequency (Hz)</th>
<th>Amplitude (High 5 mm/Low 2.5 mm)</th>
<th>Rest (s)</th>
<th>Modality</th>
<th>Number of Series per Exercise*</th>
</tr>
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<tbody>
<tr>
<td>1 → 4</td>
<td>30</td>
<td>35</td>
<td>Low</td>
<td>60</td>
<td>Static</td>
<td>a b c d e f g h</td>
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<tr>
<td>5 → 9</td>
<td>45</td>
<td>40</td>
<td>High</td>
<td>60</td>
<td>Dynamic + Static</td>
<td>3 1 1 1 1 1 1 1</td>
</tr>
<tr>
<td>10 → 14</td>
<td>60</td>
<td>40</td>
<td>High</td>
<td>45</td>
<td>Dynamic</td>
<td>3 3 3 1 1 1 1 1</td>
</tr>
<tr>
<td>15 → 19</td>
<td>60</td>
<td>40</td>
<td>High</td>
<td>45</td>
<td>8 s principle</td>
<td>3 3 3 1 1 1 1 1</td>
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<tr>
<td>20 → 24</td>
<td>60</td>
<td>30</td>
<td>High</td>
<td>30</td>
<td>8 s principle</td>
<td>3 3 3 1 1 1 1 1</td>
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<tr>
<td>Midtests (25 → 26)</td>
<td>30</td>
<td>30–35</td>
<td>Low</td>
<td>30</td>
<td>Dynamic + Static</td>
<td>3 3 3 1 1 1 1 1</td>
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<td>25 → 29</td>
<td>30–45</td>
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<td>High</td>
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<td>Dynamic</td>
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<td>30 → 34</td>
<td>45–60</td>
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<td>35 → 39</td>
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<tr>
<td>40 → 44</td>
<td>60</td>
<td>35</td>
<td>High</td>
<td>15</td>
<td>8 s + Dynamic</td>
<td>3 3 3 2 1 1 1 1</td>
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<tr>
<td>Posttests (45 → 47)</td>
<td>60</td>
<td>35–40</td>
<td>High</td>
<td>15</td>
<td>8 s + Dynamic</td>
<td>2 2 2 1 1 1 1 1</td>
</tr>
</tbody>
</table>

Notes: *Exercises: (a) squat, (b) deep squat, (c) wide stance squat, (d) one-legged squat, (e) lunge, (f) toes-stand, (g) toes-stand deep, (h) moving heels.

1Dynamic: slowly going up (2 seconds), slowly going down (2 seconds).

2Dynamic + static: the first two series were performed in a dynamic way, the last series in a static way.

38 s principle: four repetitions performed in a dynamic way, 4 seconds static performance, four repetitions in a dynamic way, static performance until the end of the exercise.
**Muscle mass.**—A multislice computed tomography (CT) scan (Siemens Sensation 16; Forcheim, Germany) delivered axial slices of the right upper leg which were analyzed with the program Volume (Siemens). If necessary, corrections were made for artefacts (e.g., varix clips). The midpoint between the medial edge of the greater trochanter and the intercondylar fossa of the patella was determined, and subsequently a 2 mm-thick axial image (1 mm above and 1 mm below this midpoint) was further analyzed. This procedure was repeated 3 cm above and 3 cm below the midpoint. Muscle tissue area was segmented by using standard Hounsfield Units ranges for skeletal muscle (0–100) and bone marrow with similar Hounsfield Units as those of skeletal muscle, as this tissue was also seen as muscle tissue. Test–retest reliability, evaluated by repeated scans within 2 weeks in an extra group of 12 older men, yielded an intra-class correlation coefficient of 0.99. Measurements were performed in the University Hospital and were executed by an expert radiologist.

**Statistical Analysis**

One-way analysis of variance (ANOVA) was used to test for differences between the groups at baseline. The changes over time in isometric strength, explosive strength, and muscle mass were analyzed by repeated-measures ANOVA. Contrast analysis was used to assess between- and within-group differences. All analyses were executed using Statistica 6.1 (Statsoft, Tulsa, OK). Level of significance was set at \( p \leq 0.05 \).

**RESULTS**

**Dropouts and Training Compliance**

No adverse side effects of the intervention were reported in the training groups. All dropouts were related to personal reasons (5) or health problems (8), none of which, according to the physician, related to the training program. The average overall adherence (number of exercise classes attended as a percentage of the total number of classes) to the training program was 87.6% in the WBV group and 87.1% in the FIT group. Only the results of the participants with a minimal compliance rate of 66% are reported. Therefore, two participants of the FIT group were not included in the analysis. Table 2 shows the basic characteristics of the remaining participants (WBV: \( n = 25 \), FIT: \( n = 25 \), CON: \( n = 32 \)). No significant baseline differences were detected between the groups in age, body mass, body mass index, maximal oxygen uptake (\( \text{VO}_{2max} \)), isometric strength, explosive strength, and muscle mass. \( \text{VO}_{2max} \) was determined by gas analysis during a graded maximal bicycle test.

**Outcome Measurements**

**Isometric strength.**—Isometric strength of the men changed significantly over time (\( p < .001 \)), and this change was different for the three groups (\( p = .009 \)). Both the WBV and FIT groups showed significant improvements in muscle strength (9.8% [\( p = .005 \)] and 13.1% [\( p < .001 \)], respectively), whereas no changes were detected in the CON group (\( -0.6\% \), \( p = .838 \)) (Figure 1). The changes in both the WBV and FIT groups were different from those in the CON group (\( p = .026 \) and \( p = .004 \), respectively). Training effect was not significantly different between the training groups (\( p = .467 \)).

**Explosive strength.**—Jump performance of the men changed significantly over time (\( p < .001 \)), and this change was different for the three groups (\( p = .031 \)). Contrast analysis showed a significant improvement in explosive strength in the WBV group (10.9\%, \( p < .001 \)) and FIT group (9.8\%, \( p < .001 \)) but no significant changes in the CON group (1.8\%, \( p = .499 \)) (Figure 2). Training effect was not significantly different between the training groups (\( p = .808 \)); both the WBV and FIT groups were significantly different from the CON group (\( p = .017 \) and \( p = .030 \), respectively).

**Muscle mass.—**Muscle mass of the men changed significantly over time (\( p < .001 \)), and this change was different for the three groups (\( p < .001 \)), with a significant increase in the WBV (3.4\%, \( p < .001 \)) and FIT (3.8\%, \( p < .001 \)) groups but no changes in the CON group (\( -0.7\% \), \( p = .180 \)) (Figure 3). Training effect was similar in the WBV and FIT groups (\( p = .465 \)); both groups differed significantly from the CON group (\( p < .001 \) and \( p < .001 \), respectively).

Isometric strength of the women increased significantly over time (\( p < .001 \)), and this change was different for the three groups (\( p = .03 \)). The WBV and FIT groups improved significantly (12.3\%, \( p < .001 \) and 10.6\%, \( p = .005 \), respectively), whereas no changes were detected for the CON group (2.2\%, \( p = .468 \)). Training effect was not significantly different between the training groups (\( p = .714 \)). Only the changes in the WBV group were significantly different from the changes in the CON group (\( p = .01 \)). The relative change over time in isometric strength was comparable for men and women of the WBV group (\( p = .609 \)), FIT group (\( p = .194 \)), and CON group (\( p = .643 \)).

**DISCUSSION**

To our knowledge, this is the first randomized controlled trial investigating the effects of 1-year WBV training on...
muscle performance and muscle mass in community-dwelling men older than 60 years. In line with results previously reported in older women (15), our current findings confirm a WBV-induced increase in isometric and explosive muscle strength in men. Additionally, our study indicates that this improvement is not solely due to neurological adaptations, but also to an increase in muscle mass.

Isometric muscle strength increased by about 10% in the WBV group participants. The relative improvement was comparable for men and women, indicating that both sexes
respond similarly to vibration stimuli. The gains in isometric strength were similar to those induced by an equal number of fitness training sessions. In a previous study in older women, we reported slightly higher increases in isometric strength after 6 months of WBV and FIT training (15% and 18.4%, respectively) (15). In the FIT group of the present study, the gain in muscle strength was also slightly lower than expected from other studies using high resistance and/or explosive strength training (23,24). However, training intensity of the present resistance training program was designed according to the recommendations of the American College of Sports Medicine to improve, not to maximize strength (19).

It has been hypothesized that vibration training may improve muscle strength by facilitating neural control following tonic vibration reflex muscle activation (i.e., increase in motor unit synchronization, co-contraction of the synergist muscle, increased inhibition of the antagonist muscles, and increased ability of motor units to fire briefly at very high rates) (24–26). However, the extent to which WBV might induce muscle hypertrophy remained to be clarified (17,18). To our knowledge, this is the first study providing direct evidence for a WBV-induced increase in muscle mass. This increase was similar in magnitude (3%–4%) than the one observed in the FIT group. A coefficient of determination of 0.27 ($r = 0.52$) between the gains in muscle strength and the gains in muscle mass suggests that, next to neural adaptations, also hypertrophic adaptations contribute to the functional improvements after long-term WBV.

The gain in explosive strength in this study is in line with previous reports (14–16,27), and may indicate that WBV specifically trains fast-twitch fibers, although it remains unclear if there is a difference in hypertrophic response between slow- and fast-twitch fibers. Whereas high-frequency electrical stimulation has been shown to elicit a preferential recruitment of fast-twitch fibers (28–30), recent studies with electrostimulation resistance training and frequency-controlled muscle vibration suggest that slow-twitch fibers are also activated and develop hypertrophy (31,32). Because aging is associated with a preferential loss in size and number of fast-twitch fibers (33), future (biopsy) studies could examine the WBV-induced changes at the level of the individual muscle fibers.

Our findings may have important clinical implications. WBV does not only improve muscle function but, because of its hypertrophic effect, may potentially improve health outcome by reducing and/or reversing the age-related process of sarcopenia and its related disorders. Maintaining muscle strength and muscle mass may be critically important for elderly persons to perform daily activities and to remain independent (34). In this regard, the present results suggest that WBV training may potentially be useful as a low-impact training method to enhance muscle mass and muscle strength of the lower limb muscles in older individuals. In contrast with conventional resistance training, WBV training minimizes the need for conscious exertion and stress on the musculoskeletal, respiratory, and cardiovascular systems. In the context of this study, the compliance of the WBV program was excellent. The vibration sessions were experienced as pleasant and both socially and physically rewarding. After the study, most participants wanted to continue to participate, suggesting that WBV might be feasible over longer time periods, in apparently healthy older individuals.

The hypertrophy due to WBV might also be beneficial for other populations with atrophy. For instance, it is well understood that muscle dysfunction due to disuse decreases muscle mass and strength, which leads to daily activity limitations and increases the risk of falls in older persons. Therefore, WBV might be a useful strategy to prevent or reverse muscle loss in this population.

Figure 3. Muscle mass in the control (CON), fitness (FIT), and whole-body vibration (WBV) groups at baseline (PRE) and at 1 year (POST). Results of repeated-measures analysis of variance are presented as means ± standard errors. *Significant pre–post difference within group ($p < .05$).
known that long-term exposure to microgravity induces skeletal muscle atrophy in astronauts (35,36). In this respect, it has recently been shown that frequency-controlled muscle vibration during 55 days of bed rest results in a preservation of muscle strength and an increase in myofiber size (32). Vibration training may also have implications for patients in various clinical settings, including patients with neuromuscular diseases or those in rehabilitation.

Conclusion

The present study supports the use of WBV as an efficient training stimulus to enhance isometric and explosive muscle strength, and muscle mass, in community-dwelling men older than 60 years. WBV training deserves further research in institutionalized elderly persons in whom the control of sarcopenia is even more critical for health and independence.

ACKNOWLEDGMENTS

This study was supported by grant G-0521-05 from the ‘Fonds voor Wetenschappelijk Onderzoek’ (FWO) to S. Boonen, S. Verschueren, C. Delecluse, and A. L. Claesens. S. Boonen is senior clinical investigator of FWO and holder of the Roche & GSK Leuven University Chair in Osteoporosis. S. Verschueren is postdoctoral fellow of the ‘Bijzonder Onderzoeksfonds’ (BOF) (Katholieke Universiteit Leuven).

We thank all the participants for their cooperation. We also thank Guus Van Der Meer, Jelte Tempelaars, and Nick De Poort for help in the design of the WBV training program and for logistic support.

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Received May 8, 2006
Accepted September 19, 2006
Decision Editor: Luigi Ferrucci, MD, PhD