CLINICAL STUDY

Acute Effects of Whole-Body Vibration Training on Endothelial Function and Cardiovascular Response in Elderly Patients with Cardiovascular Disease
A Single-Arm Pilot Study

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Summary

The aim of this single-arm pilot study was to determine the effects of whole-body vibration training (WBVT) on endothelial function in elderly patients with cardiovascular diseases, as well as its safety. A total of 20 elderly patients with stable cardiovascular diseases underwent WBVT, which consisted of five static resistance training exercises (squats, wide stance squats, toe-stands, squats + band, and front lunges). The parameters of WBVT included vertical vibrations, 30 Hz frequency, and a 3-mm peak-to-peak amplitude. Each vibration session lasted 30 seconds, with 120 seconds of rest between sessions. Before and after WBVT, the reactive hyperemia peripheral arterial tonometry index (RH-PAT index) and transcutaneous oxygen pressure (tcPO2) were recorded as a measure of endothelial function and peripheral blood circulation. Systolic blood pressure, diastolic blood pressure, heart rate, and arterial oxygen saturation of pulse oximetry (SpO2) were measured at each rest interval as well as before and after WBVT. All patients completed our WBVT protocol without adverse events. The RH-PAT index significantly increased following WBVT (1.42 to 2.06, \( P < 0.001 \)). There were no significant changes in heart rate (\( P = 0.777 \)), systolic blood pressure (\( P = 0.183 \)), diastolic blood pressure (\( P = 0.925 \)), or SpO2 (\( P = 0.248 \)) during WBVT. In conclusion, we demonstrated the acute effects of WBVT on endothelial function, with no reports of adverse events. These findings support the need for further randomized controlled studies to investigate the long-term effects of WBVT.

Key words: Vascular endothelial dysfunction, Resistance training, Reactive hyperemia peripheral arterial tonometry index, Rehabilitation

Endothelial cells have an essential role in maintaining homeostasis, such as vascular tone, blood fluidity, and coagulation. With aging, the progression of endothelial dysfunction and deterioration is caused by complex molecular pathophysiology. Impaired vascular endothelial function can indicate an early subclinical stage of arteriosclerosis and can be associated with various comorbidity and cardiovascular diseases. The reactive hyperemia peripheral arterial tonometry index (RH-PAT index) is a useful method for invasive assessment of peripheral endothelial function. In addition, it reflects the nitric oxide dependent vasodilation, which can lead to reactive hyperemia in the microvasculature of the fingertip. Recently, the RH-PAT index value has become widely recognized as a prognostic indicator of cardiovascular events and mortality. Therapeutic interventions, including comprehensive lifestyle modifications, such as weight loss and exercise, are known to improve endothelial dysfunction, wherein a single session of exercise has been shown to improve endothelial function. However, appropriate exercise therapy for elderly patients has not been established because several studies have suggested that different exercise modalities may have different effects on endothelial function and arterial stiffness.

Recently, whole-body vibration training (WBVT) has emerged as an alternative resistance training. In WBVT, vibrations are used to generate regular up and down movements that result in repetitive muscle spindle reflexes and an increase in the blood flow to skeletal muscles, which increases tissue perfusion. As some previous randomized control trials for elderly participants have re-

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ported the improvements in overall health including physical function, bone loss, and cardiovascular health. WBVT is widely used in various fields, including sports, general health, and rehabilitation.

Although resistance training is an established exercise therapy to increase muscle mass and prevent disability, it may not be always feasible because it may cause arterial stiffness and excessive blood pressure elevation. As an alternative method, WBVT has clinical advantages for elderly patients. First, exercise with vibrations has already been shown to induce a 10-30% increased muscle activity compared to the exercise without vibration. Because the increases in blood flow and shear stress are associated with exercise intensity or muscle contractions, WBVT induce muscle contractions could more efficiently improve endothelial dysfunction than the conventional exercise training. Second, this alternative method is a safety exercise modality because WBVT is known to have a small influence of cardiovascular responses in healthy adults and patients with hypertension. In addition, static exercise is recommended in WBVT because this modality activates reflexive muscle contractions more effectively compared to dynamic exercise and presents a lower risk of falls. However, there are limited data on the safety of WBVT in patients with cardiovascular diseases and its acute effects on endothelial function and cardiovascular response have never been evaluated.

Therefore, the aim of this study was to evaluate the acute effect of WBVT on endothelial function and cardiovascular response in elderly patients with cardiovascular diseases as well as its safety.

**Methods**

This was a single-arm interventional study that was conducted at the Department of Cardiac Rehabilitation and Cardiovascular Disease Management at Kitasato University East Hospital between April 2017 and July 2017. Patients with cardiovascular diseases who were 65 years or older, on guideline-based pharmacotherapy, and had undergone cardiac rehabilitation for at least 6 months prior to enrollment in the study were included. Patients with symptomatic chronic heart failure according to a New York Heart Association functional class of III-IV, atrial fibrillation, recent history of cardiovascular events (<6 months), treated with hemodialysis, those who needed assistance for walking, and those who had non-cardiac disease limiting activity in their daily lives were excluded. This study protocol was approved by the Ethics Committee of Kitasato University Hospital and conformed to the ethical guidelines of the Declaration of Helsinki. All patients signed a written informed consent prior to participation.

**Study protocol:** Patients were not allowed to partake in intense physical activity, any drinks containing caffeine or alcohol, or consume tobacco on the day of the visit. Figure 1 showed the study protocol and measurements procedure. The endothelial function, peripheral blood circulation, and cardiovascular responses were measured prior to and following WBVT. Measurements were recorded in a semi-dark and quiet temperature-controlled room (22-26°C) to minimize potential diurnal variations. Before recording the measurements, the patients rested on a bed in the supine position for 15 minutes.

**WBVT intervention:** WBVT was provided using a vibration platform (Power plate; Performance health system, Chicago, IL). In patients with heart failure, the function and volume of the quadriceps and triceps surae muscles were lower compared to healthy subjects and directly associated with exercise capacity. Therefore, we referred to some randomized control trials for elderly participants and used original protocol to efficiently stimulate these muscles. All patients were instructed to perform the five static resistance trainings of squats, wide stance squats, toe-stands, squats + band (hip abduction), and front lunges (Figure 2). The order of five static resistance exercises was randomized. The patients were instructed to hold on to the handle bar of the platform during WVBT. Details about the five postures were provided as follows (Figure 2A). Squats: to stand with their knees bent at 70-80° flexion (Figure 2B). Wide stance squats: to stand with feet twice the shoulder width apart and knees bent at 70-80° flexion (Figure 2C). Toe-stands: to stand on tiptoes (Figure 2D). Squats + band: to stand with their knees bent to 70-80° flexion and their fastened thigh with the TheraBand, which took a load of 2.1 kg when the band was extended by twice in the length (Figure 2E). Front lunges: to stand with one foot forward and the other back at as possible and the front knee bent to 70-80° flexion. Patients were prohibited from wearing shoes in order to eliminate the cushioning effects of shoes. The WBVT parameters included vertical vibrations, a frequency of 30 Hz, and peak-to-peak amplitude of 3 mm. Each vibration session lasted for 30 seconds with a 120-second rest interval between sessions. Patients were closely monitored by a physical therapist and instructed to report any negative adverse reactions during WBVT. Systolic blood pressure,
diastolic blood pressure, heart rate and arterial oxygen saturation of pulse oximetry (SpO₂) were measured at each rest interval, and prior to and following WBVT. Blood pressure and SpO₂ were measured in patients in the standing position using a sphygmomanometer and a pulse oximeter, respectively.

**Measurement of endothelial function:** The reactive hyperemia peripheral arterial tonometry index (RH-PAT index) was measured as a surrogate for endothelial function using a finger plethysmograph (EndoPAT2000; Itamar Medical, Caesarea, Israel). We measured the digital pulse amplitudes in patients while they were in the supine position for 5 minutes at baseline and following the induction of reactive hyperemia using a forearm cuff occlusion for 5 minutes. The data were automatically digitized and computed using the Endo-PAT2000 software. The RH-PAT index was defined as the ratio of the mean post-deflation signal (in the 90 to 120 seconds post-deflation interval) to the baseline signal in the hyperemic finger and was normalized using the same ratio in the contralateral finger. This value was multiplied by a baseline correction factor calculated by the Endo-PAT2000 software.

**Measurements of peripheral blood circulation and cardiovascular responses:** The transcutaneous oxygen pressure (tcPO₂) was used to measure the peripheral blood circulation using a transcutaneous oxygen pressure device (TCM400; Radiometer, Tokyo, Japan) before and after WBVT for 15 minutes each. Two probes heated to 43.5°C were attached to the first intermetatarsal space on the dorsum of both patients’ feet. The measurement of tcPO₂ was initiated once the patients were stabilized, which was defined as a change of < 5 mmHg in tcPO₂ within 1 minute following the attachment of the probes to the feet. For the assessment of hemodynamics, stroke volume, cardiac output, and systemic vascular resistance were measured using a finger sphygmomanometer (Finometer; Finapres Medical System BV, Arnhem, The Netherlands) for 15 minutes pre- and post-WBVT. The cardiac output and systemic

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Figure 2. Five dynamic resistance trainings in the WBVT protocol. A: Squats, B: Wide stance squats, C: Toe-stands, D: Squats + band, and E: Front lunges. WBVT indicates whole-body vibration training.
vascular resistance were adjusted according to body surface area and expressed as a cardiac index and a systemic vascular resistance index, respectively. The mean values of the peripheral blood circulation and cardiovascular responses were calculated for the last 5 minutes in measurement time prior to and following WBVT. These mean values were adopted as the representative values for pre-WBVT and post-WBVT.

Heart rate was monitored throughout the study using a digitized Holter electrocardiogram (FM-120; Fukuda Denshi, Tokyo, Japan). The heart rate variability was measured using R-R intervals obtained at a temporal resolution of 1 ms. The power spectra of the high-frequency (HF) (0.15-0.40 Hz) and low-frequency (LF) components (0.04-0.15 Hz) of heart rate variability were analyzed using the maximum entropy method with MemCalc (TARAWA; GMS, Tokyo, Japan). The HF and the ratio (LF/HF) reflected the cardiac parasympathetic activity and the LF reflected the sympathetic activity. According to a guideline for the standards of measurement of heart rate variability,20 the mean values of the autonomic activity were calculated for the last 5 minutes in the measurement time prior to, during, and following WBVT and were adopted as representative values for pre-, during-, and post-WBVT. Systolic blood pressure, diastolic blood pressure, heart rate, and SpO2 were measured prior to and following WBVT and during each rest interval with patients in the standing position.

Date collection: Data on the demographics and characteristics of patients were extracted from their electronic medical records collected upon their enrollment in the study. The collected data included age, sex, height, weight, body mass index, left ventricular ejection fraction, history of cardiovascular diseases, comorbidity, medication, brain natriuretic peptide, and estimated glomerular filtration rate.

Statistical analysis: Normally distributed continuous variables were expressed as a mean ± standard deviation, while categorical variables were expressed as numbers and percentages. The variables were compared among pre-, during, and post-measurements, including endothelial function, cardiovascular response, and peripheral blood circulation using a paired t-test or a repeated measure analysis of variance. All statistical analyses were performed using SPSS version 24.0 (SPSS statistics; IBM Corporation, Tokyo, Japan). We considered P values less than 0.05 to be statistically significant.

Results

Study population: A total of 20 patients with cardiovascular diseases were enrolled in the study. All patients were in stable condition, receiving guideline-based pharmacotherapies, and capable of walking without assistance. The characteristics and demographic data of the patients are summarized in Table I. This study cohort consisted of 12 males (60.0%) with a median age of 76.0 (72.0-79.7) years and a median left ventricular ejection fraction of 64.0 (47.8-66.7)%. With regard to cardiovascular diseases, 25% had old myocardial infarction, 30% had angina pectoris, 50% had chronic heart failure, 10% had myopathy, and 50% had valvular heart disease. A total of 45% of patients were prescribed angiotensin-converting enzyme inhibitors, 35% were prescribed angiotensin-receptor blockers, 10% were prescribed beta-blockers, and 7% received diuretic agents at study commencement.

The effect of WBVT on endothelial function: The effect of WBVT on endothelial function is shown in Figure 3. The RH-PAT index value was significantly increased post-WBVT (1.42 to 2.06, P < 0.001).

The effects of WBVT on peripheral blood circulation and hemodynamics: The effects of WBVT on hemodynamics and peripheral blood circulation are shown in Table II. While stroke volume (57.0 mL to 61.0 mL, P = 0.002), cardiac index (2.10 L/minute/m2 to 2.45 L/minute/m2, P = 0.001), and tcPO2 (54.7 mmHg to 65.3 mmHg, P = 0.002) were significantly increased, the systemic vascular resistance index (1846 dyn · seconds · cm−5 · m2 to 1710 dyn · seconds · cm−5 · m2, P < 0.001) significantly decreased post-WBVT.

Assessment of cardiovascular responses during WBVT: No adverse events, including vertigo, falls, or lethal arrhythmias, were reported in all patients during WBVT. The changes in cardiovascular responses and automatic activity during WBVT are shown in Tables III, IV. There were no significant changes in heart rate (P = 0.777), systolic blood pressure (P = 0.183), diastolic blood pressure (P = 0.925), SpO2 (P = 0.248), LF/HF (P = 0.558), and HF (P = 0.105) during WBVT. Although there was no significant change in LF/HF (P = 0.754) pre-WBVT and during WBVT, they decreased post-WBVT (P = 0.010).

Discussion

This single-arm, interventional trial investigated the acute effects of WBVT on endothelial function and cardiovascular response in elderly patients with stable cardiovascular diseases. Our study demonstrated several findings. First, the endothelial function as evaluated using the RH-PAT index was improved following WBVT among the various subgroups, including elderly patients and those with a mild reduction in ejection fraction and coronary risk factors. Second, there were no adverse events, such as vertigo, falls, lethal arrhythmias, or excessive elevations of the systolic blood pressure or heart rate, during WBVT.

As WBVT is reportedly effective in improving muscle strength,20 bone loss,17 and arterial stiffness,16 it is widely used in various fields, such as sports, general health, and rehabilitation. However, the effects of WBVT on endothelial function have not been elucidated in patients with cardiovascular diseases. To our knowledge, this is the first study to investigate the acute effects of WBVT on endothelial function and hemodynamics in elderly patients with cardiovascular diseases. Our results did not reveal abnormal cardiovascular responses, such as excessive elevations of blood pressure and heart rate, or other adverse events during WBVT. Although WBVT is known to carry no risk to the cardiovascular system, its safety was never evaluated among elderly patients with cardiovascular diseases. The present study suggested that WBVT may be a safe and effective exercise therapy for elderly patients with cardiovascular diseases.
increase in venous return caused by the activated tonic vasoconstriction mediated by nitric oxide synthase, which is an important mechanism underlying reactive hyperemia in the microvasculature of the fingertips. A previous study revealed that oxygen uptake during WBVT increased three times the value without WBVT and that the increase was associated with the frequency and amplitude of WBVT. Based on these data, WBVT may contribute to the improvement of peripheral blood circulation and hemodynamics, which can result in an increased blood flow velocity and shear stress due to the increase in the oxygen uptake requirements during WBVT.

As endothelial function was assessed using the RH-PAT index, which reflected the nitric oxide-dependent vasodilation leading to reactive hyperemia in the microvasculature of the fingertips, exercise-induced shear stress and the activation of nitric oxide may be integral factors contributing to improving endothelial function. A previous animal study revealed that acute exercise increased vasodilation by increasing endothelial calcium influx and calcium-dependent nitric oxide release. Elevated shear stress or regular exercise activated the AKT-mediated phosphorylation of endothelial nitric oxide synthase producing nitric oxide in an animal model and patients with coronary artery disease. In addition, acute resistance training led to an increase in the angiogenic factors, including vascular endothelial growth factor, and activated the matrix metalloproteinase system, leading to an elevation in the circulating endothelial progenitor cells.

### Table I. Patient Characteristics

| Characteristic                          | All patients (n = 20) |
|----------------------------------------|-----------------------|
| Age (years)                            | 76.0 (72.0-79.7)      |
| Age > 75, n (%)                        | 13 (65.0)             |
| Male, n (%)                            | 12 (60.0)             |
| Height (cm)                            | 160.0 (150.3-160.0)   |
| Weight (kg)                            | 54.3 (47.8-66.7)      |
| Body mass index                        | 22.0 (18.6-24.6)      |
| Current smoker, n (%)                  | 0 (0)                 |
| Brachial-ankle pulse wave velocity (cm/second) | 1724 (1382-1984)     |
| Left ventricular ejection fraction (%) | 64.0 (47.8-66.7)      |
| Left ventricular ejection fraction < 50%, n (%) | 5 (25.0)            |
| Ischemic heart disease, n (%)          | 10 (50.0)             |
| Old myocardial infarction, n (%)       | 5 (25.0)              |
| Angina pectoris, n (%)                 | 6 (30.0)              |
| PCI, n (%)                             | 8 (40.0)              |
| CABG, n (%)                            | 2 (10.0)              |
| Chronic heart failure, n (%)           | 10 (50.0)             |
| NYHA functional class I/II, n (%)      | 12 (60.0) / 8 (40.0)  |
| Cardiomyopathy, n (%)                  | 2 (10.0)              |
| Valvular heart disease, n (%)          | 10 (50.0)             |
| Hypertension, n (%)                    | 13 (65.0)             |
| Diabetic mellitus, n (%)               | 7 (35.0)              |
| Dyslipidemia, n (%)                    | 18 (90.0)             |
| Brain natriuretic peptide (pg/dL)      | 52.5 (37.0-96.7)      |
| eGFR (mL/minute/1.73 m²)               | 57.5 (43.7-66.5)      |
| ACEI, n (%)                            | 9 (45.0)              |
| ARB, n (%)                             | 6 (30.0)              |
| Beta-blockers, n (%)                   | 10 (50.0)             |
| Calcium channel blocker, n (%)         | 9 (45.0)              |
| Diuretics agents, n (%)                | 7 (35.0)              |

Values are median (interquartile range) or number (%). PCI indicates percutaneous coronary intervention; CABG, coronary artery bypass graft; NYHA, New York Heart Association; eGFR, estimated glomerular filtration rate; ACEI, angiotensin-converting enzyme inhibitor; and ARB, angiotensin-receptor blocker.

**Figure 3.** Effects of WBVT on the endothelial function. Values are median (interquartile range). WBVT indicates whole-body vibration training; and RHI, reactive hyperemia peripheral arterial tonometry index.

WBVT is known to affect physical performance and hemodynamics. An increased oxygen supply to the skeletal muscles and blood flow velocity in the popliteal artery was observed via the widening of small vessels and the increase in venous return caused by the activated tonic vibration reflex following vibratory stimulation. A previous study revealed that oxygen uptake during WBVT increased three times the value without WBVT and that the increase was associated with the frequency and amplitude of WBVT. Based on these data, WBVT may contribute to the improvement of peripheral blood circulation and hemodynamics, which can result in an increased blood flow velocity and shear stress due to the increase in the oxygen uptake requirements during WBVT.

As endothelial function was assessed using the RH-PAT index, which reflected the nitric oxide-dependent vasodilation leading to reactive hyperemia in the microvasculature of the fingertips, exercise-induced shear stress and the activation of nitric oxide may be integral factors contributing to improving endothelial function. A previous animal study revealed that acute exercise increased vasodilation by increasing endothelial calcium influx and calcium-dependent nitric oxide release. Elevated shear stress or regular exercise activated the AKT-mediated phosphorylation of endothelial nitric oxide synthase producing nitric oxide in an animal model and patients with coronary artery disease. In addition, acute resistance training led to an increase in the angiogenic factors, including vascular endothelial growth factor, and activated the matrix metalloproteinase system, leading to an elevation in the circulating endothelial progenitor cells.
Table II. The Effects of WBVT on Hemodynamics and Peripheral Blood Circulation during WBVT

|                      | Pre-WBVT     | Post-WBVT    | P value |
|----------------------|--------------|--------------|---------|
| Stroke volume (mL)   | 57.0 (46.7-60.2) | 61.0 (54.0-77.0) | 0.002   |
| Cardiac index (L/minute/m²) | 2.10 (1.95-2.56) | 2.45 (2.28-3.12) | 0.001   |
| Systemic vascular resistance index (dyn-seconds-cm⁻³-m²⁻¹) | 1846 (1638-1919) | 1710 (1419-1956) | 0.008   |
| tcPO₂ (mmHg)         | 54.7 (42.7-61.2) | 65.3 (54.4-70.3) | 0.002   |

Values are median (interquartile range). WBVT indicates whole-body vibration training; and tcPO₂, transcutaneous oxygen pressure.

Table III. Changes in Vital Signs during WBVT

|                      | Pre-WBVT     | A   | B   | C   | D   | E-1 | E-2 | Post-WBVT |
|----------------------|--------------|-----|-----|-----|-----|-----|-----|-----------|
| Heart rate (beats/minute) | 71.0 (64.7-74.5) | 70.5 (67.5-76.0) | 72.5 (65.2-78.0) | 72.5 (67.2-78.0) | 74.0 (69.0-78.0) | 74.0 (69.0-78.5) | 74.0 (68.2-78.2) | 72.0 (66.5-74.0) |
| Systolic blood pressure (mmHg) | 121.0 (110.7-128.5) | 122.0 (112.0-126.0) | 124.0 (114.0-128.0) | 124.5 (119.0-130.0) | 124.5 (117.5-130.5) | 124.5 (117.5-130.5) | 124.5 (119.5-130.0) | 120.0 (111.5-124.0) |
| Diastolic blood pressure (mmHg) | 68.0 (65.5-73.2) | 68.0 (64.0-70.5) | 68.0 (65.5-74.5) | 69.0 (67.5-72.5) | 69.0 (67.5-72.5) | 69.0 (67.5-72.5) | 69.0 (63.5-72.0) | 64.0 (61.5-68.0) |
| SpO₂ (%)               | 98.0 (97.0-98.0) | 97.0 (95.0-98.0) | 96.0 (95.0-98.0) | 96.0 (95.0-97.2) | 96.0 (94.0-98.0) | 96.0 (94.0-98.0) | 96.0 (94.0-98.0) | 98.0 (97.0-98.0) |

Values are median (interquartile range). A: Squats; B: Wide stance squats; C: Toe-stands; D: Squats + band; E-1: Front lunges (right side); E-2: Front lunges (left side). WBVT indicates whole-body vibration training; and SpO₂, arterial oxygen saturation of pulse oximetry.

Table IV. Changes in Automatic Activity during WBVT

|                      | Pre-WBVT   | During WBVT  | Post-WBVT  | P value Pre- versus during-WBVT | P value Pre- versus post-WBVT |
|----------------------|------------|--------------|------------|--------------------------------|------------------------------|
| LF (msec⁻²)         | 112.8 (56.9-136.4) | 106.0 (59.2-130.4) | 101.1 (45.1-128.9) | 0.583                          | 0.239                        |
| HF (msec⁻²)         | 43.2 (16.6-136.0)   | 70.3 (37.0-136.0)   | 70.5 (37.0-107.4)   | 0.099                          | 0.308                        |
| LF/HF                | 1.96 (1.40-4.57)    | 1.87 (1.03-3.35)    | 1.61 (0.85-2.95)    | 0.754                          | 0.010                        |

Values are median (interquartile range). LF, low-frequency component; and HF, high-frequency component.

which have an important role in improving endothelial function. Thus, acute exposure to WBVT may improve endothelial function through increasing the shear stress and vasodilator substance.

Endothelial dysfunction is known to be a risk factor that can be modified by exercise, which was reported as an effective strategy for correcting endothelial dysfunction regardless of the type of training. However, several previous studies revealed that high-intensity resistance training or aerobic exercises failed to improve endothelial function and arterial stiffness. As overloaded exercise training can cause an acute increase in plasma noradrenaline and inflammatory cytokines, the setting of exercise should be cautiously determined to provide effective therapy, particularly in elderly people.

The intensity of WBVT was determined by four factors, including vibration direction, frequency, peak-to-peak amplitude, and the duration of vibration. However, data on the optimal vibratory parameters are limited, especially in elderly individuals. A systematic review to investigate the effects of WBVT in healthy elderly participants revealed that WBVT had few advantages in improving muscular strength compared with traditional exercise. Because there are no guidelines for WBVT and several studies used different protocols for their evaluation, it is unclear whether their results were reflective of WBVT. Thus, further studies are needed to determine the optimal modalities of WBVT.

There were some limitations to our study. The main limitation was the small sample size and lack of control groups. Our results suggested that WBVT may be an appropriate exercise method for patients with various coronary risk factors. However, the small number of patients included in our study may have reduced the statistical power. In addition, since we excluded patients who required assistance for walking and those who had limited daily activity, we cannot be certain whether WBVT can be applied to patients with frailty or to those who cannot perform traditional exercise training. Second, the retention effect of WBVT is unclear because we measured endothelial function and cardiovascular response only two points before and after WBVT. Two previous studies have reported that arterial stiffness acutely decreases after WBVT and the decreased returned to resting levels within 60 minutes of WBVT. In the acute effects of the conventional exercise training, the improvement of endothelial function returned to baseline levels by 30-60 minutes although these differences are likely to relate to the study population and exercise settings. Finally, because we did not measure vasoactive substances such as nitric oxide and its signaling pathway, we were unable to determine whether the WBVT-induced shear stress and increased nitric oxide were the main causes of the ΔRH-PAT index.

In conclusion, our study demonstrated the acute effects of WBVT on endothelial function and cardiovascular response. With the increase of the aging population,
WBVT may be an effective strategy to improve endothelial function as an alternative resistance training. Our results support the need for randomized controlled trials to investigate the effects of WBVT on endothelial function in elderly patients with cardiovascular diseases.

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Disclosure

Conflicts of interest: The authors declare no conflict of interests.

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