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Research Article

Acute Effects of Whole-Body Vibration Exercise on Hemorheological and Oxidative Stress Parameters: A Preliminary Study

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ABSTRACT

Previous studies reported that WBV can increase peripheral blood flow and oxygenation. Investigating the acute effects of a single WBV exercise session on hemorheological parameters, blood glucose levels, balance, flexibility, and oxidative stress markers (total oxidant status [TOS], total antioxidant status [TAS], and oxidative stress index [OSI]) was the goal of this study. All participants engaged in a WBV exercise program consisting of nine exercises, each lasting 60 seconds, for a total of 13 minutes. Flexibility, balance, visual analog pain scale (VAS) scores, heart rate, blood pressure, capillary blood glucose levels, hemorheological parameters, and TOS/TAS were assessed before and immediately after the WBV session. Twelve healthy active male volunteers (mean age: 20.83±2.59 years; mean height: 174.79±5.26 cm; mean weight: 79.21±14.87 kg) participated in the study. Hematocrit values and heart rate significantly increased, while blood glucose levels decreased following the WBV protocol ($p<0.05$). A single session of WBV exercise did not affect TAS, TOS, or OSI; however, erythrocyte deformability measured at 5.33 and 9.49 Pa significantly increased post-exercise ($p<0.05$). No significant differences were found in the other parameters. A single session of WBV exercise appears to acutely improve erythrocyte deformability while not affecting oxidative stress parameters.

INTRODUCTION

Whole-body vibration (WBV) exercise is a moderate neuromuscular resistance training method that induces automatic physiological adaptations (Rittweger et al., 2010). Additionally, WBV has been demonstrated to be a successful strategy for lowering body fat and improving muscle strength, bone mineral density, balance, and coordination (de Ruiter et al., 2003; Trans et al., 2009). During WBV, individuals stand on a vibrating platform at a specific frequency and amplitude while performing various exercises. WBV exercise is a practical, safe, and cost-effective method to improve health across various populations (Gusso et al., 2016; Hidalgo-Santamaria et al., 2017). Research indicates that acute vibration exercise may have a distinct warm-up effect and increase muscle power, even though the benefits of WBV over traditional resistance training are still unclear (Rittweger, 2010). WBVE acutely increases heart rate, blood flow, and oxygen consumption while enhancing muscle activation, neuromuscular efficiency, and proprioception (Kerschan-Schindl et al., 2001; Martin & Park, 1997). It also stimulates hormone secretion (e.g., growth hormone, testosterone) and improves respiratory function and blood rheology. These effects vary based on vibration parameters and individual characteristics (AlBaiti et al., 2024).

Given the association between increased blood flow and shear stress with exercise intensity or muscle contraction, WBV may enhance endothelial function more effectively than traditional exercise regimens. Within the field of biorheology, hemorheology investigates the properties of blood flow and its interaction with the blood vessels (Muravyov et al., 2002). Hemorheological parameters, such as erythrocyte deformability, erythrocyte aggregation, whole blood, and plasma viscosity, are critical for optimal blood flow (Marossy et al., 2009). These parameters play key roles in tissue perfusion due to their contribution to hydrodynamic resistance in blood vessels.

The primary elements of hemorheology-erythrocyte deformability, red blood cell (RBC) aggregation, and plasma viscosity-are closely related to changes in oxidative stress (Tikhomirova et al., 2011). Furthermore, depending on the type, intensity, and duration of the exercise, there can be significant changes in blood rheology and oxidative stress levels (Findikoglu et al., 2014; Kilic-Toprak et al., 2012, 2015; Yalcin et al., 2003). Athletic ability is another important factor influencing these changes (Yalcin et al., 2003).

Given the above-mentioned cardiovascular consequences of WBV exercise, we postulated that hemorheological parameters—intimately linked to blood flow—might change after an acute episode of WBV exercise. However, it remains unclear whether changes in plasma viscosity, RBC deformability, and oxidative stress parameters occur after performing WBV exercise. Our study hypothesis was that WBVE may have acute positive effects on the circulatory system, including oxidative stress markers, plasma viscosity, and RBC deformability.

METHODS

Participants

In the study, twelve male volunteers who were in good health and engaged in daily physical activities but did not participate in organized sports took part (mean age: 20.83 ± 2.59 years; mean height: 174.79 ± 5.26 cm; mean weight: 79.21 ± 14.87 kg). The participants were students at Pamukkale University Faculty of Sport Sciences, generally healthy, but had not engaged in any resistance training for at least six months before the study and did not regularly participate in sports (Table 1). The study followed the standards specified by the Declaration of Helsinki (60116787-020/77490; November 13, 2018).

Table 1
Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Age 18-25 years	
Healthy male	Presence of chronic health issues (e.g., cardiovascular, respiratory, musculoskeletal disorders)
Sedentary lifestyle	Use of alcohol, tobacco, or performance-enhancing substances during the study period
Signed informed consent form	Non-compliance with the study protocol or withdrawal of consent during the study
No injuries or conditions preventing physical activity	

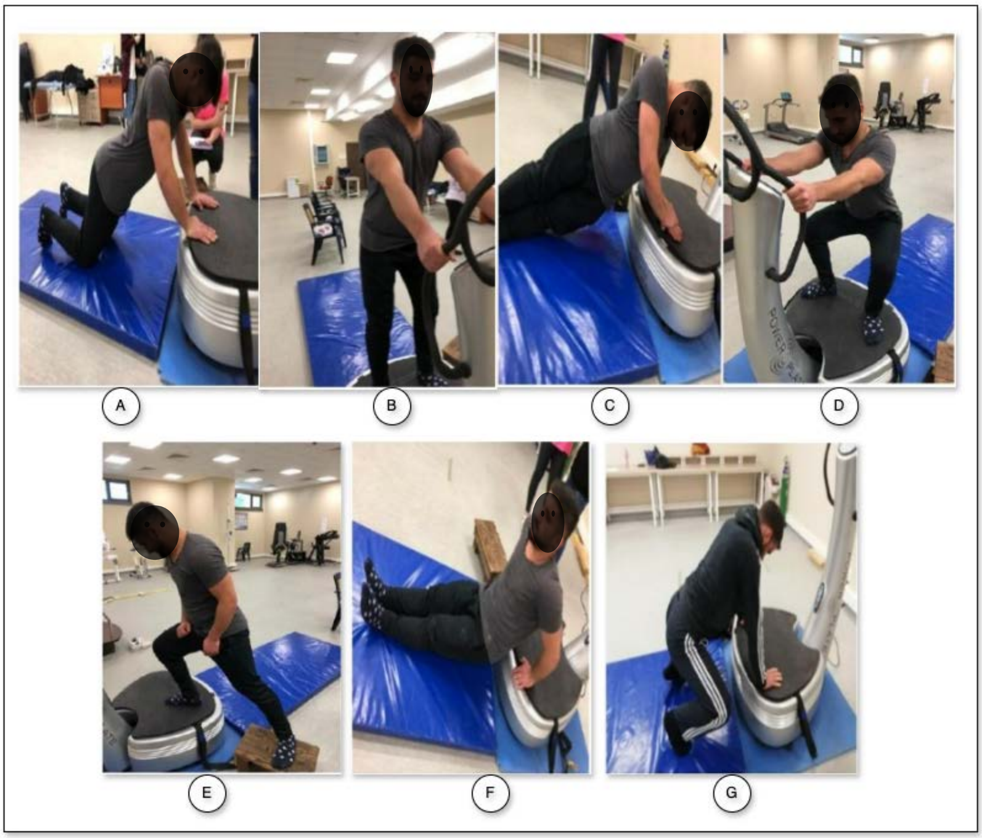
Data Collection Tools

To evaluate the effects of a single WBV exercise session, various physiological and biochemical parameters were assessed both before and immediately after the session. Flexibility was measured using the sit-and-reach test, while balance was evaluated with one-leg stance test. Pain perception was assessed using the Visual Analog Scale (VAS). Heart rate and blood pressure were recorded with automated devices, and capillary blood glucose levels were measured using a glucometer. Hematocrit values were analyzed with a blood analyzer, and erythrocyte deformability was assessed using ektacytometry. Oxidative stress markers, including total oxidant status (TOS) and total antioxidant status (TAS), were measured spectrophotometrically, with the oxidative stress index (OSI) calculated from the TOS/TAS ratio. The following methods were employed for data collection:

Whole Body Vibration Exercise Protocol

All participants completed a WBV exercise program consisting of nine exercises (push-up, squat, right plank, sumo squat, left plank, right lunge, triceps dip, left lunge, and shoulder press). Each exercise was performed for 60 seconds on a vibration device following a 5-minute warm-up at Pamukkale University Faculty of Sport Sciences. The training used a vibrating platform (Compex Power Plate®, London, UK) set at 35 Hz and amplitude of 4 mm. A 30-second rest was given between exercises (Rauch et al., 2010). To standardize the damping effects, participants wore only socks. The exercise session lasted 13 minutes, including a warm-up and cool-down with active stretching. The Borg scale (6-20) was used to record participants' perceived difficulty. Exercises were performed under the supervision of a physiotherapist at the same time each day (Figure 1).

Figure 1
Exercise Executed During the Main Phase of a Training Session on a Vibration Platform



Note. (A) Push Up; (B) Squat; (C) Right and left plank; (D) Sumo squat; (E) Right and left lunge; (F) Triceps dip; (G) Shoulder press

One-Leg Standing Test for Balance

Subjects were instructed to stand on one leg while the other was elevated, ensuring the foot did not touch the standing ankle. They focused on a point at eye level during the open-eye test. Arms were crossed over the chest, and timing began when the subject was stable. The test was terminated if the subject uncrossed their arms, adjusted their foot, or touched the floor (Springer et al., 2007).

Sit-and-Reach Test for Flexibility

Flexibility was assessed using a sit-and-reach box. Participants removed their shoes, stretched their legs, and pressed their feet against the box. If a person received a positive score, they went above and beyond, but if they received a poor score, they did not. The best trial was recorded after participants held the position for five seconds while reaching as far forward as possible (Mayorga-Vega et al., 2014).

Visual Analog Pain Scale (VAS)

Pain severity was measured using the Visual Analog Scale (VAS). With "no pain" at one end and "maximum pain" at the other, the VAS was a 100 mm horizontal line (Collins et al., 1997).

Heart Rate, Blood Pressure, and Blood Glucose Level

An automated oscillometric monitor (Rossmax S150) was used to assess blood pressure and heart rate. Capillary blood glucose levels were measured with a digital device (On Call Plus).

Samples and Measurements

Venous blood samples (10 mL) were collected before and immediately after exercise, following an 8-hour fasting period. Samples were transferred to the Physiology Laboratory, and hemorheological tests were conducted within three hours. Blood samples were centrifuged to assess oxidative stress markers, and the serum was stored at -80°C for later analysis (Baskurt et al., 2009).

Erythrocyte Deformability Measurements

Using an ektacytometer and laser diffraction analysis, the deformability of red blood cells was assessed (LORCA, RR Mechatronics). A low hematocrit suspension of red blood cells was subjected to shear stress in a Couette system, and the elongation index (EI) was computed based on the geometry of the diffraction pattern (Hardeman et al., 2007).

Plasma Viscosity Determination

A wells–brookfield cone-plate rotating viscometer was used to measure the viscosity of plasma at 37°C and a shear rate of 375 s^{-1}. Plasma was obtained by centrifugation at 1400g for 6 minutes (Rosencranz & Bogen, 2006).

Total Oxidant Status (TOS) Determination

Erel's colorimetric method measured the total oxidant status (TOS). The assay involved oxidation reactions that correlated with the concentration of oxidants in the serum. Results were reported in micromolar hydrogen peroxide equivalents per liter (μmol H_2O_2 Equiv./L) (Erel, 2005).

Total Antioxidant Status (TAS) Measurement

Erel also developed an automated colorimetric method for measuring total antioxidant status (TAS). The serum's antioxidant properties inhibited the formation of radicals, allowing for the calculation of TAS, reported in mmol Trolox Equiv./L (Erel, 2004).

Calculation of Oxidative Stress Index (OSI)

The oxidative stress index (OSI) was determined using the following formula as the percentage ratio of TOS to TAS (Kosecik et al., 2005).

$$OSI = TOS\ (\mu mol\ H_2O_2\ Equiv./L) / TAS\ (mmol\ Trolox\ Equiv./L) \times 100.$$

Data Analysis

SPSS 25.0 was used for statistical analysis. The mean ± standard deviation (SD) was used to express continuous variables. For normalcy, the Shapiro-Wilk test was employed. The Wilcoxon Signed Rank test or the Paired Samples t-test was employed depending on the parametric test assumptions. p-values less than 0.05 were regarded as statistically significant. A power analysis indicated that including 10 subjects would provide 80% power with a 95% confidence level.

RESULTS

The study group consisted of ten male participants with a mean age of 20.83 ± 2.59 years, an average height of 174.79 ± 5.26 cm, and a mean body weight of 79.21 ± 14.87 kg.

Several parameters such as flexibility, balance, pain intensity, plasma viscosity, and blood pressure showed no statistically significant changes from baseline after completing the WBV exercise protocol (p > 0.05; Table 2- 3).

Table 2
Flexibility, Balance and Pain Values of the Subjects

Variables	Before exercise	After exercise	p
Flexibility (cm)	20.54 ± 12.44	22.54 ± 12.17	0.072
Balance (right; second)	50.92 ± 21.22	52.58 ± 17.28	1.000
Balance (left; second)	54.67 ± 14.86	55.67 ± 15.01	0.655
Pain (VAS)	0 ± 0	0.83 ± 1.64	0.109

*Note.*Values are expressed as means ± SD

Table 3
Plasma Viscosity, Hematocrit, Heart Rate Values, Blood Glucose Level and Blood Pressure of the Subjects

Variables	Before exercise	After exercise	p
Plasma Viscosity (375 s^{-1})	1.50 ± 0.23	1.88 ± 0.52	0.076
Hematocrit (%)	46.92 ± 3.03	51.08 ± 4.48 *	0.021
Heart Rate (beats/min)	76.27 ± 12.56	90.45 ± 21.59 *	0.011
Blood glucose level (mmol/L)	94.75 ± 15.12	76.92 ± 3.58*	0.008
Blood pressure (systolic; mm Hg)	119.75 ± 12.78	117.08 ± 10.1	0.439
Blood pressure (diastolic; mm Hg)	74.75 ± 7.23	78 ± 5.38	0.253

Note. Values are expressed as means ± SD. *p < 0.05 difference from before exercise

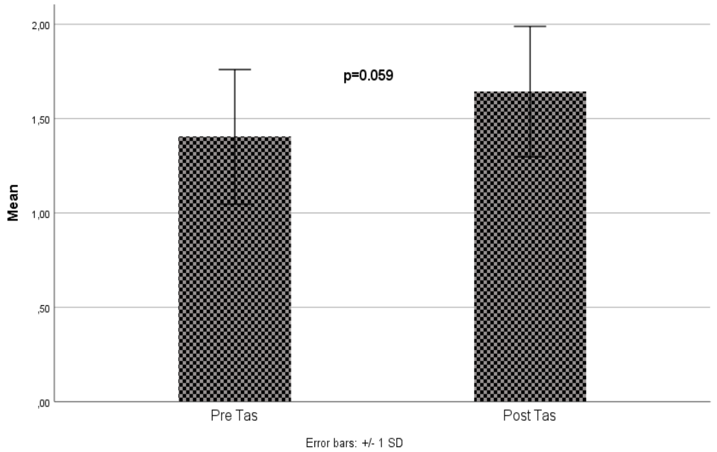
However, three key parameters did show significant changes. Hematocrit values increased notably after the WBV exercise (p = 0.021). Heart rate also significantly increased following the WBV protocol (p = 0.011). Blood glucose levels decreased significantly after the WBV session (p = 0.008; Table 3). Erythrocyte deformability, measured at shear stresses of 5.33 and 9.49 Pa, significantly increased post-exercise (p = 0.042 and p = 0.043, respectively; Table 4). The WBV protocol did not produce any significant changes in TAS, TOS, or OSI regarding oxidative stress markers (Figures 2-4).

Table 4
Erythrocyte Deformability (EI) Values of the Subjects at Different Shear Stresses

Shear stress (Pa)	Before Exercise	After Exercise	p
0.30	0.06 ± 0.04	0.07 ± 0.02	0.298
0.53	0.13 ± 0.08	0.14 ± 0.04	0.476
0.95	0.20 ± 0.1	0.23 ± 0.05	0.202
1.69	0.30 ± 0.1	0.34 ± 0.04	0.111
3.00	0.40 ± 0.08	0.44 ± 0.04	0.070
5.33	0.48 ± 0.07	0.52 ± 0.03*	**0.042**
9.49	0.54 ± 0.05	0.57 ± 0.02*	**0.043**
16.87	0.58 ± 0.04	0.61 ± 0.02	0.084
30.00	0.60 ± 0.05	0.63 ± 0.03	0.171

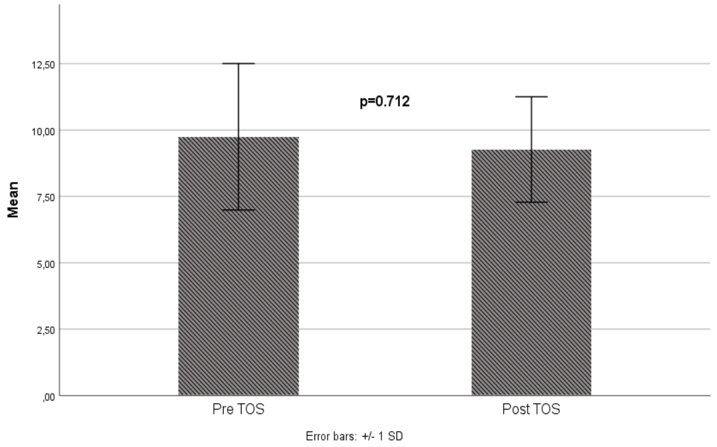
Note. Values are expressed as means ± SD; EI: elongation index; Pa: pascal. *p < 0.05 difference from before exercise

Figure 2
Total Antioxidant Status (TAS) of the Subjects



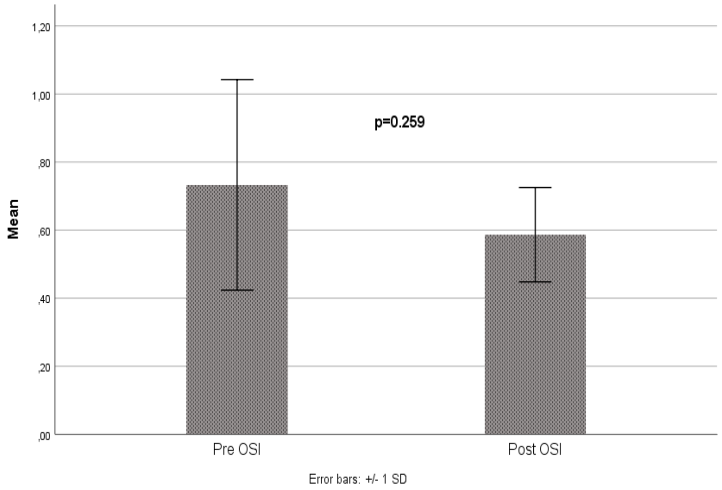
Note. Values are expressed as means ± SD

Figure 3
Total Oxidant Status (TOS) of the Subjects



Note. Values are expressed as means ± SD.

Figure 4
Oxidative Stres Index (OSI) of the Subject



Note. Values are expressed as means ± SD

DISCUSSION

This research investigated the acute effects of WBV exercise on hemorheological parameters, oxidative stress parameters, cardiovascular response, and musculoskeletal responses in young, healthy men. The current study highlighted several findings. First, erythrocyte deformability improved following a single session of WBV exercise. Second, WBV exercise was associated with elevated hematocrit and heart rate values while blood glucose levels decreased. Third, there were no significant effects on TAS, TOS, OSI, plasma viscosity, and blood pressure after acute WBV exercise.

To our knowledge, this study is the first to look into how WBV exercise affects oxidative stress markers, plasma viscosity, and RBC deformability in young, healthy people. In recent years, WBV exercise has gained popularity as a form of physical activity, utilizing mechanical vibrations from oscillating platforms as an alternative to resistance training. WBV exercise is widely applied in various fields, including sports, general health, and the rehabilitation of clinical disorders such as fibromyalgia, cerebral palsy, and chronic obstructive pulmonary disease (Aoyama et al., 2019; Brun et al., 2010).

In the current literature, studies exploring the effects of vibration exercise on postural stability and flexibility present inconsistent results. Some of the acute influences of vibration exercise is the development of flexibility; some studies report no effect on flexibility (Dallas et al., 2015; Donahue et al., 2016). It was suggested that WBV might change the properties of the intramuscular connective tissue, reduce the tendon's stiffness and hysteresis, and possibly change the properties of other passive skeletal structures linked to the range of motion of a particular joint, such as the knee (Donahue et al., 2016). Dallas et al. have reported that the acute effect of vibration training increases flexibility. There is no common fact about how long this increase continues (Dallas et al., 2015). Di Giminiani et al. found in a single study of young adults that WBV significantly improves hamstring and lower back flexibility and seems useful in increasing flexibility in clinical populations (Di Giminiani et al., 2010). Conversely, Dichin et al. discovered that postural sway modifications occurred in various sensory contexts when repeated bouts of personalized WBV were applied (Dickin et al., 2012). In our study, we found an increase in flexibility, consistent with the data in the literature, but it was not statistically significant. We think that its reason is timecontinues, which continues until flexibility evaluation.

Some publications have evaluated the acute efficiency of vibration training for balance as beneficial (Daray et al., 2011). Nevertheless, not all authors have identified such favorable effects. It is reported that no significant alterations in balance or joint position sensation occurred after vibration (Cunha et al., 2019). However, we found no differences in balance after vibration. The reason for this difference may be that we measured the equilibrium measurement with a one-leg standing test instead of a digital measurement such as postural sway.

According to evidence, vibration exercise may lower blood glucose levels (Di Loreto et al., 2004). The most plausible explanation would be increased glucose absorption from the blood, most likely into the muscles, since insulin and glucagon levels were unaffected in that study (Rittweger et al., 2010). The decrease in blood glucose levels we observed in response to acute exercise is consistent with the data in the literature.

However, the precise mechanical effects of vibrations combined with physical activity, particularly regarding internal body alterations induced by WBV exercise, are still not fully understood. The literature indicates that repetitive and cumulative vibration, combined with physical exercise, can enhance blood flow (Gattner et al., 2024; Sá-Caputo et al., 2017). Previous studies suggest that WBV exercise may improve peripheral blood circulation and hemodynamics, potentially leading to increased blood flow velocity and shear stress due to heightened oxygen uptake demands during WBV training (Button et al., 2007; Games et al., 2015; Kerschan-Schindl et al., 2001; Sá-Caputo et al., 2017). While many authors report positive effects of vibration training on the human body, some studies have failed to demonstrate similar benefits (Beijer et al., 2015; Gattner et al., 2024; Sá-Caputo et al., 2018).

Endothelial dysfunction is recognized as a modifiable risk factor influenced by exercise, which has been documented as an effective approach for improving endothelial function, irrespective of the training modality (Ashor et al., 2015). Numerous studies indicate that high-intensity resistance training or aerobic activities may not enhance endothelial function or reduce arterial stiffness (Choi et al., 2016; Kitzman et al., 2013. Over-exertion during exercise training can lead to a sudden increase in plasma noradrenaline and inflammatory cytokines; thus, the exercise environment must be carefully controlled to ensure effective treatment (Harris et al., 2008; Okamoto et al., 2009). One mechanism behind these effects is vasodilation brought on by elevated nitric oxide (NO) levels in the vascular endothelium, which causes smooth muscle relaxation (Johnson et al., 2014). Although WBV exercise increases blood flow and shear stress, leading to elevated levels of vasodilatory chemicals like NO, it also affects the release of vascular endothelial growth factor (VEGF), a key proangiogenic factor found in muscle fibers and endothelial cells (Gattner et al., 2024).

Games et al.'s investigation shows that WBV improves tissue oxygenation and nourishment by increasing peripheral blood flow (Games et al., 2015). According to the findings, applying vibration caused a tendency for peripheral blood flow to rise by about 14% more than that seen in the placebo condition (Button et al., 2007). The peripheral vascular system is extremely sensitive to vibration exposure (Robbins et al., 2014). Cochrane et al. demonstrated the beneficial impact of vibration therapies on circulatory system efficiency, particularly regarding oxygen absorption capacity, in both young and older individuals (Cochrane et al., 2008).

Hemoconcentration is a widely accepted phenomenon documented in the literature, occurring due to a single activity-whether submaximal or maximal-. This phenomenon arises from at least five distinct mechanisms: redistribution of erythrocytes within the vascular system, an increase in red blood cell count due to splenic contraction, plasma enrichment with lymphatic proteins, water loss through sweating during thermoregulation, and translocation of water into muscle cells (Brun et al., 1998; 2010). A single session of prolonged physical exertion can cause a 15% drop in plasma volume, leading to hemoconcentration (a rise in blood viscosity and hematocrit, but no discernible change in the total quantity and volume of erythrocytes; Kenney et al., 2022). Ahmadizad observed a concomitant reduction in plasma volume accompanied by elevations in plasma viscosity, red blood cell count, hemoglobin, and hematocrit following a single session of resistance exercise in young, healthy males (Ahmadizad & El-Sayed, 2005). These temporary alterations in hemorheological markers validate the phenomenon of hemoconcentration. A study by Romagnoli et al. yielded analogous results, evaluating the effects of a single aerobic workout on a cycle ergometer in young, untrained individuals (Romagnoli et al., 2014). According to Gattner H. et al., the first and last physical training sessions on the vibration platform led to a greater decrease in plasma volume percentage than a group of women who performed physical activities without the vibration element. However, no research has looked into how the WBV exercise model affects plasma viscosity in the short term (Gattner et al., 2024). Our data suggest that a single session WBV exercise seems to lead to an acute increase in plasma viscosity and hematocrit values, in accordance with the literature. The above scenario matches hemoconcentration. Hct determines the blood's ability to carry oxygen. Raising Hct to supra-normal levels to improve exercise performance in fit, well-trained athletes (Reinhart, 2016). However, when the vasomotion ability of arteries is overreached, the increase in blood viscosity and systemic resistance may also result in a decline in performance for higher levels. It may be inferred from the post-exercise Hct readings that hemoconcentration occurred in our physically active subjects because the type, duration, and intensity of WBVE were insufficient to cause an extra Hct rise.

Physical exercise is one of the many variables that can affect blood hemorheology (Kenney et al., 2022; Szanto et al., 2021). However, scientific reports do not evaluate RBC deformability and plasma viscosity in response to WBV exercise. Although our study did not examine blood flow, endothelial dysfunction, arterial stiffness, and/or plasma inflamatuary inflammatory cytokine levels, changes in plasma viscosity, RBC deformability, and hematocrit levels, which are the main determinants of blood flow, were investigated. An increase was found in all parameters with a single session of WBV exercise. As far as we know, this study is the first to examine RBC deformability, plasma viscosity, and oxidative stress markers in response to vibration exercise. The significant improvement in erythrocyte deformability found in our study is beneficial for tissue perfusion from a hemorheological perspective. The degree of training may be a determinant of RBC deformability (Cakir-Atabek et al., 2009; Connes et al., 2004). According to Connes et al., when exercise causes local hypoxia beyond the anaerobic threshold, lactate builds up in the body, leading to decreased deformability in physically inactive individuals and increased deformability in trained individuals (Connes et al., 2004). Gattner H et al. found that individual training in the experimental and control groups did not alter the elongation index (Gattner et al., 2024). Given that the impact of WBV can be regarded as the cumulative effect of vibrations and physical activity, these findings indicate that incorporating vibrations into training does not diminish RBC deformability in physically inactive individuals (Gattner et al., 2024). Among women undergoing repeated WBV training, Gattner H et al. observed a slight enhancement in erythrocyte deformability at low shear stress, suggesting a beneficial effect on capillary blood flow and an increase in long-term tissue oxygenation. The validity of these alterations is supported by the substantial elevation in elongation index values noted in these experiments under shear stresses of 0.3 and 0.58 Pa following the most recent WBV session, compared to the initial training condition (Gattner et al., 2024). Prolonged exposure to vibrations may elicit a more pronounced response from the circulatory system. Resistance training improves erythrocyte deformability in young, healthy people, according to research by Kilic-Toprak et al. The erythrocyte index increased throughout the third and fourth weeks of exercise when compared to baseline values.

Furthermore, following the recent training conducted in week 12, this measure experienced another rise (Kilic-Toprak et al., 2012). Given the growing interest in these techniques, it is wise to investigate how vibration affects the human body because there is little empirical evidence of its impact on blood hemorheological indices. A significant barrier to comparing results from various studies is the methodological approach employed. A review of the literature highlights the need for meticulous selection of vibration parameters, including intensity, frequency and amplitude. A committee of specialists has recently developed guidelines for the application of vibration (van Heuvelen et al., 2021; Wuestefeld et al., 2020). Since greater erythrocyte deformability enhances oxygen transport to muscle capillaries even at high levels of Hct, it is possible to interpret the increase in RBC deformability that we observed in response to WBVE in our study population as an adaptive mechanism to WBVE regimen. We selected 35 Hz frequency, as the literature reports that 30–35 Hz is the most commonly used frequency range in WBVE for inducing physiological changes (Donahue et al., 2016; Tan et al., 2024).

Exercises of varied intensity have substantially affected oxidative stress and blood rheology (Kilic-Toprak et al., 2012; Yalcin et al., 2003). Exercise's effects on blood rheology depend on the type, duration, and intensity of the activity and the athlete's athletic ability (Yalcin et al., 2003). Serum TAS, TOS, and OSI levels did not significantly alter during our investigation. In contrast to the current study, a prior investigation in our lab revealed that a single session of eccentric isokinetic exercise did not affect oxidative stress measures (Kilic-Toprak et al., 2018). Oxidative stress is critical in the pathogenesis of various diseases and is influenced by factors such as age and physical fitness level. Our results are particularly notable as this is the first study in the literature to examine the acute effects of WBV exercise in healthy, young, active males. However, there are limited studies investigating the short- and long-term relationship between WBV exercise and oxidative stress in humans. The interventions have neutral or potentially positive effects on blood coagulation, fibrinolysis, inflammation, oxidative stress, and cardiovascular, microvascular, and endothelial functions. A study on 21 females examined the effects of WBV exercise on oxidative stress markers in women with fibromyalgia (FM) compared to healthy controls (CT). The results showed that a single WBV session improved oxidative and antioxidant balance by increasing SOD and CAT in CT, while in FM, it reduced TBARS and FRAP, lowered CAT, and increased SOD, indicating enhanced stress response adaptation (Santos et al., 2019). Another study investigated the effects of six weeks of WBVT on oxidative stress markers, plasma irisin levels, and body composition in women with FM. Forty participants were randomized into WBVT or untrained (UN) groups. After the intervention, the WBVT group showed higher irisin levels, lower TBARS levels, and reduced visceral adipose tissue mass compared to the UN group. These findings suggest that WBVT enhances redox balance, increases irisin levels, and reduces visceral fat, promoting better oxidative status in women with FM (Dos Santos et al., 2023).

These studies also investigated the effect of long-term WBV exercise. For example, Dos Santos JM et al. investigated the effects of WBVE on oxidative stress markers and in women with fibromyalgia. They showed that 6 weeks of WBVE provided lower thiobarbituric acid reactive substances (TBARS) levels in patients with fibromyalgia (Dos Santos et al., 2023).

Limitations

The relatively small sample size, the absence of a control group, and the lack of data on the homogeneity of the subject group can be considered limitations of the current study.

CONCLUSION

This pilot study suggests that acute WBV exercise improves erythrocyte deformability, which can be considered an advantage for improved tissue perfusion from a hemorheological perspective. On the other hand, plasma viscosity, blood pressure and oxidative stress parameters seem not to be affected after acute WBV exercise. However, additional studies are warranted to reassess these findings in a larger group over a longer training period using the WBV exercise model.

PRACTICAL IMPLICATIONS

Overall, our findings demonstrated that a single WBV exercise session initially had a favorable impact on erythrocyte deformability but had no effect on oxidative stress indicators. Our results could be used as a guide for coaches and exercise physiologists in future research utilizing this workout regimen.

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ICPESS), which took place in Nevşehir, Cappadocia, Turkey, from December 4-6, 2018, a portion of this work was given orally.

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Authors' Contributions

The study was conceived and designed by all authors. Data collection was carried out by the first and second authors. Data analysis and interpretation were conducted by the first, third, and fourth authors. The drafting of the manuscript and/or its critical revision was a joint effort by all four authors. All authors read and approved the final version of the manuscript to be published.

Declaration of Conflict Interest

There are no conflicts of interest, according to the authors. The sponsor had no role in the research that might have affected the findings of this study, according to the authors. The authors assume full responsibility for the accuracy and objectivity of the data they give and the interpretation they discuss. The 1st and 2nd authors contributed equally to this work.

Ethics Statement

According to the most recent version of the Declaration of Helsinki and the guidelines set forth by the Pamukkale Non-Interventional Clinical Research Ethics Committee (60116787-020/77490; 13/11/2018), the study was carried out. Written agreement was obtained from each participant once they were briefed about the study and its tests.

REFERENCES

Ahmadizad, S., & El-Sayed, M. S. (2005). The acute effects of resistance exercise on the main determinants of blood rheology. *Journal of sports sciences*, *23*(3), 243–249. https://doi.org/10.1080/02640410410001730151

AlBaiti, S., Arumugam, A., & Nawayseh, N. (2024). Acute neuromuscular responses to whole-body vibration in healthy individuals: A systematic review. *J Electromyogr Kinesiol*, 77:102888. https://doi.org/10.1016/j.jelekin.2024.102888

Aoyama, A., Yamaoka-Tojo, M., Obara, S., Shimizu, E., Fujiyoshi, K., Noda, C., Matsunaga, A., & Ako, J. (2019). Acute Effects of Whole-Body Vibration Training on Endothelial Function and Cardiovascular Response in Elderly Patients with Cardiovascular Disease. *International heart journal*, *60*(4), 854–861. https://doi.org/10.1536/ihj.18-592

Ashor, A. W., Lara, J., Siervo, M., Celis-Morales, C., Oggioni, C., Jakovljevic, D. G., & Mathers, J. C. (2015). Exercise modalities and endothelial function: a systematic review and dose-response meta-analysis of randomized controlled trials. *Sports medicine (Auckland, N.Z.)*, *45*(2), 279–296. https://doi.org/10.1007/s40279-014-0272-9

Baskurt, O. K., Boynard, M., Cokelet, G. C., Connes, P., Cooke, B. M., Forconi, S., Liao, F., Hardeman, M. R., Jung, F., Meiselman, H. J., Nash, G., Nemeth, N., Neu, B., Sandhagen, B., Shin, S., Thurston, G., & Wautier, J. L. (2009). New guidelines for hemorheological laboratory techniques. *Clinical hemorheology and microcirculation*, *42*(2), 75–97. https://doi.org/10.3233/CH-2009-1202

Beijer, Å., Degens, H., Weber, T., Rosenberger, A., Gehlert, S., Herrera, F., Matthias Kohl-Bareis, Jochen Zange, Bloch, W., & Rittweger, J. (2014). Microcirculation of skeletal muscle adapts differently to a resistive exercise intervention with and without superimposed whole-body vibrations. *Clinical physiology and functional imaging*, *35*(6), 425–435. https://doi.org/10.1111/cpf.12180

Brun, J. F., Khaled, S., Raynaud, E., Bouix, D., Micallef, J. P., & Orsetti, A. (1998). The triphasic effects of exercise on blood rheology: which relevance to physiology and pathophysiology?. *Clinical hemorheology and microcirculation*, *19*(2), 89–104.

Brun, J. F., Varlet-Marie, E., Connes, P., & Aloulou, I. (2010). Hemorheological alterations related to training and overtraining. *Biorheology*, *47*(2), 95–115. https://doi.org/10.3233/BIR-2010-0563

Button, C., Anderson, N., Bradford, C., Cotter, J. D., & Ainslie, P. N. (2007). The effect of multidirectional mechanical vibration on peripheral circulation of humans. *Clinical physiology and functional imaging*, *27*(4), 211–216. https://doi.org/10.1111/j.1475-097X.2007.00739.x

Cakir-Atabek, H., Atsak, P., Gunduz, N., & Bor-Kucukatay, M. (2009). Effects of resistance training intensity on deformability and aggregation of red blood cells. *Clinical hemorheology and microcirculation*, *41*(4), 251–261. https://doi.org/10.3233/CH-2009-1176

Choi, Y., Akazawa, N., Zempo-Miyaki, A., Ra, S. G., Shiraki, H., Ajisaka, R., & Seiji, M. (2016). Acute Effect of High-Intensity Eccentric Exercise on Vascular Endothelial Function in Young Men. *Journal of strength and conditioning research*, *30*(8), 2279–2285. https://doi.org/10.1519/JSC.0000000000000536

Cochrane, D. J., Sartor, F., Winwood, K., Stannard, S. R., Narici, M. V., & Rittweger, J. (2008). A comparison of the physiologic effects of acute whole-body vibration exercise in young and older people. *Archives of physical medicine and rehabilitation*, *89*(5), 815–821. https://doi.org/10.1016/j.apmr.2007.09.055

Collins, S. L., Moore, R. A., & McQuay, H. J. (1997). The visual analogue pain intensity scale: what is moderate pain in millimetres?. *Pain*, *72*(1-2), 95–97. https://doi.org/10.1016/s0304-3959(97)00005-5

Connes, P., Bouix, D., Py, G., Prefaut, C., Mercier, J., Brun, J. F., & Caillaud, C. (2004). Opposite effects of in vitro lactate on erythrocyte deformability in athletes and untrained subjects. *Clinical hemorheology and microcirculation*, *31*(4), 311–318.

Cunha, P. M., Ribeiro, A. S., Nunes, J. P., Tomeleri, C. M., Nascimento, M. A., Moraes, G. K., Sugihara, P., Barbosa, D. S., Venturini, D., & Cyrino, E. S. (2019). Resistance training performed with single-set is sufficient to reduce cardiovascular risk factors in untrained older women: The randomized clinical trial. Active Aging Longitudinal Study. *Archives of gerontology and geriatrics*, *81*, 171–175. https://doi.org/10.1016/j.archger.2018.12.012

Dallas, G., Paradisis, G., Kirialanis, P., Mellos, V., Argitaki, P., & Smirniotou, A. (2015). The acute effects of different training loads of whole body vibration on flexibility and explosive strength of lower limbs in divers. *Biology of sport*, *32*(3), 235–241. https://doi.org/10.5604/20831862.1163373

Daray, L., Henagan, T., Zanovec, M., Earnest, C., Johnson, L., Winchester, J., Tuuri, G., & Stewart, L. (2011). Endurance and resistance training lowers C-reactive protein in young, healthy females. *Applied physiology, nutrition, and metabolism = Physiologie appliquee, nutrition et metabolisme*, *36*(5), 660–670. https://doi.org/10.1139/h11-077

de Ruiter, C. J., van der Linden, R. M., van der Zijden, M. J., Hollander, A. P., & de Haan, A. (2003). Short-term effects of whole-body vibration on maximal voluntary isometric knee extensor force and rate of force rise. *European journal of applied physiology*, *88*(4-5), 472–475. https://doi.org/10.1007/s00421-002-0723-0

Di Giminiani, R., Manno, R., Scrimaglio, R., Sementilli, G., & Tihanyi, J. (2010). Effects of individualized whole-body vibration on muscle flexibility and mechanical power. *The Journal of sports medicine and physical fitness*, *50*(2), 139–151.

Di Loreto, C., Ranchelli, A., Lucidi, P., Murdolo, G., Parlanti, N., De Cicco, A., Tsarpela, O., Annino, G., Bosco, C., Santeusanio, F., Bolli, G. B., & De Feo, P. (2004). Effects of whole-body vibration exercise on the endocrine system of healthy men. *Journal of endocrinological investigation*, *27*(4), 323–327. https://doi.org/10.1007/BF03351056

Dickin, D. C., McClain, M. A., Hubble, R. P., Doan, J. B., & Sessford, D. (2012). Changes in postural sway frequency and complexity in altered sensory environments following whole body vibrations. *Human movement science*, *31*(5), 1238–1246. https://doi.org/10.1016/j.humov.2011.12.007

Donahue, R. B., Vingren, J. L., Duplanty, A. A., Levitt, D. E., Luk, H. Y., & Kraemer, W. J. (2016). Acute Effect of Whole-Body Vibration Warm-up on Footspeed Quickness. *Journal of strength and conditioning research*, *30*(8), 2286–2291. https://doi.org/10.1519/JSC.0000000000001014

Santos, Redha Taiar, Gonçalves, V., Kelly, V., Henrique, P., Henrique Silveira Costa, Vanessa Pereira Lima, Borja Sañudo, Mário Bernardo-Filho, da, D., Fabrício, M., Vanessa Amaral Mendonça, Rapin, A., & Cristina, A. (2023). Whole-Body Vibration Training on Oxidative Stress Markers, Irisin Levels, and Body Composition in Women with

Fibromyalgia: A Randomized Controlled Trial. *Bioengineering (Basel, Switzerland)*, *10*(2), 260. https://doi.org/10.3390/bioengineering10020260

Erel O. (2004). A novel automated direct measurement method for total antioxidant capacity using a new generation, more stable ABTS radical cation. *Clinical biochemistry*, *37*(4), 277–285. https://doi.org/10.1016/j.clinbiochem.2003.11.015

Erel O. (2005). A new automated colorimetric method for measuring total oxidant status. *Clinical biochemistry*, *38*(12), 1103–1111. https://doi.org/10.1016/j.clinbiochem.2005.08.008

Findikoglu, G., Kilic-Toprak, E., Kilic-Erkek, O., Senol, H., & Bor-Kucukatay, M. (2014). Acute effects of continuous and intermittent aerobic exercises on hemorheological parameters: a pilot study. *Biorheology*, *51*(4-5), 293–303. https://doi.org/10.3233/BIR-14012

Gattner, H., Adamiak, J., Czerwińska-Ledwig, O., Mętel, S., Kępińska-Szyszkowska, M., & Piotrowska, A. (2024). Whole Body Vibration Training Has No Effect on Vascular Endothelial and Inflammatory Markers in Young Healthy Women. *Journal of clinical medicine*, *13*(14), 4228. https://doi.org/10.3390/jcm13144228

Games, K. E., Sefton, J. M., & Wilson, A. E. (2015). Whole-body vibration and blood flow and muscle oxygenation: a meta-analysis. *Journal of athletic training*, *50*(5), 542–549. https://doi.org/10.4085/1062-6050-50.2.09

Gusso, S., Munns, C. F., Colle, P., Derraik, J. G. B., Biggs, J. B., Cutfield, W. S., & Hofman, P. L. (2016). Effects of whole-body vibration training on physical function, bone and muscle mass in adolescents and young adults with cerebral palsy. *Scientific reports*, *6*, 22518. https://doi.org/10.1038/srep22518

Hardeman, M.R., Goedhart, P., Shin, S. (2007). In: Baskurt OK, Hardeman MR, Rampling MR, Meiselman HJ, eds. Handbook of Hemorheology and Hemodynamics. Netherlands: IOS Press; 242-266.

Harris, R. A., Padilla, J., Hanlon, K. P., Rink, L. D., & Wallace, J. P. (2008). The flow-mediated dilation response to acute exercise in overweight active and inactive men. *Obesity (Silver Spring, Md.)*, *16*(3), 578–584. https://doi.org/10.1038/oby.2007.87

Hidalgo-Santamaria, M., Fernandez-Montero, A., Martinez-Gonzalez, M. A., Moreno-Galarraga, L., Sanchez-Villegas, A., Barrio-Lopez, M. T., & Bes-Rastrollo, M. (2017). Exercise Intensity and Incidence of Metabolic Syndrome: The SUN Project. *American journal of preventive medicine*, *52*(4), e95–e101. https://doi.org/10.1016/j.amepre.2016.11.021

Johnson, P. K., Feland, J. B., Johnson, A. W., Mack, G. W., & Mitchell, U. H. (2014). Effect of whole body vibration on skin blood flow and nitric oxide production. *Journal of diabetes science and technology*, *8*(4), 889–894. https://doi.org/10.1177/1932296814536289

Kenney, W.L.; Wilmore, J.H.; Costill, D.L. (2022). Cardiorespiratory Responses to Acute Exercises. In Physiology of Sport and Exercise, 8th ed.; Human Kinetics Inc.: Champaign, IL, USA, 214–238.

Kerschan-Schindl, K., Grampp, S., Henk, C., Resch, H., Preisinger, E., Fialka-Moser, V., & Imhof, H. (2001). Whole-body vibration exercise leads to alterations in muscle blood volume. *Clinical physiology (Oxford, England)*, *21*(3), 377–382. https://doi.org/10.1046/j.1365-2281.2001.00335.x

Kilic-Toprak, E., Ardic, F., Erken, G., Unver-Kocak, F., Kucukatay, V., & Bor-Kucukatay, M. (2012). Hemorheological responses to progressive resistance exercise training in healthy young males. *Medical science monitor : international medical journal of experimental and clinical research*, *18*(6), CR351–CR360. https://doi.org/10.12659/msm.882878

Kilic-Toprak, E., Yapici, A., Kilic-Erkek, O., Koklu, Y., Tekin, V., Alemdaroglu, U., & Bor-Kucukatay, M. (2015). Acute effects of Yo-Yo intermittent recovery test level 1 (Yo-YoIR1) on hemorheological parameters in female volleyball players. *Clinical hemorheology and microcirculation*, *60*(2), 191–199. https://doi.org/10.3233/CH-141844

Kilic-Toprak, E., Unver, F., Kilic-Erkek, O., Korkmaz, H., Ozdemir, Y., Oymak, B., Oskay, A., & Bor-Kucukatay, M. (2018). Increased erythrocyte aggregation following an acute bout of eccentric isokinetic exercise does not exceed two days. *Biorheology*, *55*(1), 15–24. https://doi.org/10.3233/BIR-180175

Kitzman, D. W., Brubaker, P. H., Herrington, D. M., Morgan, T. M., Stewart, K. P., Hundley, W. G., Abdelhamed, A., & Haykowsky, M. J. (2013). Effect of endurance exercise training on endothelial function and arterial stiffness in older patients with heart failure and preserved ejection fraction: a randomized, controlled, single-blind trial. *Journal of the American College of Cardiology*, *62*(7), 584–592. https://doi.org/10.1016/j.jacc.2013.04.033

Kosecik, M., Erel, O., Sevinc, E., & Selek, S. (2005). Increased oxidative stress in children exposed to passive smoking. *International journal of cardiology*, *100*(1), 61–64. https://doi.org/10.1016/j.ijcard.2004.05.069

Marossy, A., Svorc, P., Kron, I., & Gresová, S. (2009). Hemorheology and circulation. *Clinical hemorheology and microcirculation*, *42*(4), 239–258. https://doi.org/10.3233/CH-2009-1192

Martin, B. J., & Park, H. S. (1997). Analysis of the tonic vibration reflex: influence of vibration variables on motor unit synchronization and fatigue. *European journal of applied physiology and occupational physiology*, *75*(6), 504–511. https://doi.org/10.1007/s004210050196

Mayorga-Vega, D., Merino-Marban, R., & Viciana, J. (2014). Criterion-Related Validity of Sit-and-Reach Tests for Estimating Hamstring and Lumbar Extensibility: a Meta-Analysis. *Journal of sports science & medicine*, *13*(1), 1–14.

Muravyov, A. V., Draygin, S. V., Eremin, N. N., & Muravyov, A. A. (2002). The microrheological behavior of young and old red blood cells in athletes. *Clinical hemorheology and microcirculation*, *26*(3), 183–188.

Okamoto, T., Masuhara, M., & Ikuta, K. (2009). Low-intensity resistance exercise with slow lifting and lowering does not increase noradrenalin and cardiovascular responses. *Clinical physiology and functional imaging*, *29*(1), 32–37. https://doi.org/10.1111/j.1475-097X.2008.00829.x

Rauch, F., Sievanen, H., Boonen, S., Cardinale, M., Degens, H., Felsenberg, D., Roth, J., Schoenau, E., Verschueren, S., & Rittweger, J. (2010). Reporting whole-body vibration intervention studies: recommendations of the International Society of Musculoskeletal and Neuronal Interactions. *Journal of musculoskeletal & neuronal interactions*, *10*(3), 193–198.

Reinhart, W. H. (2016). The optimum hematocrit. *Clinical hemorheology and microcirculation*, *64*(4), 575–585. https://doi.org/10.3233/CH-168032

Rittweger, J. (2010). Vibration as an exercise modality: how it may work, and what its potential might be. *European journal of applied physiology*, *108*(5), 877–904. https://doi.org/10.1007/s00421-009-1303-3

Rittweger, J., Moss, A. D., Colier, W., Stewart, C., & Degens, H. (2010). Muscle tissue oxygenation and VEGF in VO-matched vibration and squatting exercise. *Clinical physiology and functional imaging*, *30*(4), 269–278. https://doi.org/10.1111/j.1475-097X.2010.00937.x

Robbins, D., Yoganathan, P., & Goss-Sampson, M. (2014). The influence of whole body vibration on the central and peripheral cardiovascular system. *Clinical physiology and functional imaging*, *34*(5), 364–369. https://doi.org/10.1111/cpf.12103

Romagnoli, M., Alis, R., Martinez-Bello, V., Sanchis-Gomar, F., Aranda, R., & Gómez-Cabrera, M. C. (2014). Blood rheology effect of submaximal exercise on young subjects. *Clinical hemorheology and microcirculation*, *56*(2), 111–117. https://doi.org/10.3233/CH-121657

Rosencranz, R., & Bogen, S. A. (2006). Clinical laboratory measurement of serum, plasma, and blood viscosity. *American journal of clinical pathology*, *125 Suppl*, S78–S86. https://doi.org/10.1309/FFF7U8RRPK26VAPY

Sá-Caputo, D. C., Paineiras-Domingos, L. L., Oliveira, R., Neves, M. F. T., Brandão, A., Marin, P. J., Sañudo, B., Furness, T., Taiar, R., & Bernardo-Filho, M. (2018). Acute Effects of Whole-Body Vibration on the Pain Level, Flexibility, and Cardiovascular Responses in Individuals With Metabolic Syndrome. *Dose-response: a publication of International Hormesis Society*, *16*(4), 1559325818802139. https://doi.org/10.1177/1559325818802139

Sá-Caputo, D., Paineiras-Domingos, L., Carvalho-Lima, R., Dias-Costa, G., de Paiva, P. C., de Azeredo, ... & Bernardo-Filho, M. (2017). Potential Effects Of Whole-Body Vibration Exercises On Blood Flow Kinetics Of Different Populations: A Systematic Review With A Suitable Approach. *African journal of traditional, complementary, and alternative medicines: AJTCAM*, *14*(4 Suppl), 41–51. https://doi.org/10.21010/ajtcam.v14i4S.6

Santos, J. M., Mendonça, V. A., Ribeiro, V. G. C., Tossige-Gomes, R., Fonseca, S. F., Prates, A. C. N., Flor, J., Oliveira, A. C. C., Martins, J. B., Garcia, B. C. C., Leite, H. R., Figueiredo, P. H. S., Bernardo-Filho, M., & Lacerda, A. C. R. (2019). Does whole body vibration exercise improve oxidative stress markers in women with fibromyalgia? *Braz J Med Biol Res*, 52(8):e8688. https://doi.org/10.1590/1414-431X20198688

Springer, B. A., Marin, R., Cyhan, T., Roberts, H., & Gill, N. W. (2007). Normative values for the unipedal stance test with eyes open and closed. *Journal of geriatric physical therapy (2001)*, *30*(1), 8–15. https://doi.org/10.1519/00139143-200704000-00003

Szanto, S., Mody, T., Gyurcsik, Z., Babjak, L. B., Somogyi, V., Barath, B., Varga, A., Adam Attila Matrai, & Nemeth, N. (2021). Alterations of Selected Hemorheological and Metabolic Parameters Induced by Physical Activity in Untrained Men and Sportsmen. *Metabolites*, *11*(12), 870. https://doi.org/10.3390/metabo11120870

Tan, J., Lei, J., Wu, S.S.X., Adam,s. R., Wu, X., Zhang, Q., et al. (2024). Modulation of Heart Rate Variability and Brain Excitability through Acute Whole-Body Vibration: The Role of Frequency. *J Hum Kinet*,25;92:111-120. https://doi.org/10.5114/jhk/183745

Tikhomirova, I. A., Oslyakova, A. O., & Mikhailova, S. G. (2011). Microcirculation and blood rheology in patients with cerebrovascular disorders. *Clinical hemorheology and microcirculation*, *49*(1-4), 295–305. https://doi.org/10.3233/CH-2011-1480

Trans, T., Aaboe, J., Henriksen, M., Christensen, R., Bliddal, H., & Lund, H. (2009). Effect of whole body vibration exercise on muscle strength and proprioception in females with knee osteoarthritis. *The Knee*, *16*(4), 256–261. https://doi.org/10.1016/j.knee.2008.11.014

van Heuvelen, M. J. G., Rittweger, J., Judex, S., Sañudo, B., Seixas, A., Fuermaier, A. B. M., Tucha, O., Nyakas, C., Marín, P. J., Taiar, R., Stark, C., Schoenau, E., Sá-Caputo, D. C., Bernardo-Filho, M., & van der Zee, E. A. (2021). Reporting Guidelines for Whole-Body Vibration Studies in Humans, Animals and Cell Cultures: A Consensus Statement from an International Group of Experts. *Biology*, *10*(10), 965. https://doi.org/10.3390/biology10100965

Wuestefeld, A., Fuermaier, A. B. M., Bernardo-Filho, M., da Cunha de Sá-Caputo, D., Rittweger, J., Schoenau, E., Stark, C., Marin, P. J., Seixas, A., Judex, S., Taiar, R., Nyakas, C., van der Zee, E. A., van Heuvelen, M. J. G., & Tucha, O. (2020). Towards reporting guidelines of research using whole-body vibration as training or treatment regimen in human subjects-A Delphi consensus study. *PloS One*, *15*(7), e0235905. https://doi.org/10.1371/journal.pone.0235905

Yalcin, O., Erman, A., Muratli, S., Bor-Kucukatay, M., & Baskurt, O. K. (2003). Time course of hemorheological alterations after heavy anaerobic exercise in untrained human subjects. *Journal of applied physiology (Bethesda, Md.: 1985)*, *94*(3), 997–1002. https://doi.org/10.1152/japplphysiol.00368.2002

Zago, M., Capodaglio, P., Ferrario, C., Tarabini, M., Galli, M. (2018). Whole-body vibration training in obese subjects: A systematic review. *PLoS One*, 13(9):e0202866. https://doi.org/10.1371/journal.pone.0202866