

Article

Acute Whole-Body Vibration Does Not Alter Passive Muscle Stiffness in Physically Active Males

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Abstract: Whole-body vibration (WBV) is a widely used training method to increase muscle strength and power. However, its working mechanisms are still poorly understood, and studies investigating the effects of WBV on muscle stiffness are scant. Therefore, the aim of this study is to investigate the acute effects of WBV on stiffness and countermovement jump (CMJ). Twenty-four recreationally active males, on separate days and in random order, performed a static squat under two different conditions: with WBV (WBV) or without vibration (CC). Muscle stiffness was assessed through the Wartenberg pendulum test, and CMJ was recorded. RM-ANOVA was employed to test differences between conditions in the above-mentioned variables. In the CC condition, stiffness was significantly lower after the exposure to the static squat ($p = 0.006$), whereas no difference was observed after the exposure to WBV. WBV and CC did not affect CMJ. No significant correlation was observed between changes in CMJ and changes in stiffness. Our results show that WBV may mitigate the reduction in muscle stiffness observed after static squats. However, current results do not support the notion that WBV exposure may account for an increase in CMJ performance.

Keywords: knee kinematics; angular velocity; pendulum test; countermovement jump; power



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1. Introduction

Whole-body vibration (WBV) consists of a sinusoidal oscillation whose characteristics can be described in terms of frequency, amplitude, phase angle, acceleration, and duration [1–3]. In WBV, acceleration is transmitted to the human body, usually standing in a squatting position, by means of a vibrating platform [2,3]. This training method is widely adopted to increase muscle strength [4] and power [5,6]. Vibrating platforms can vibrate across a wide range of frequencies (15–60 Hz) and displacements (1–10 mm). This allows the use of numerous combinations of WBV protocols that can be used to improve neuromuscular performance in humans [1]. It has been suggested that low-amplitude [6] and low-frequency [4,6] mechanical stimulation is an effective and safe exercise method to enhance the neuromuscular system and improve muscle strength [6]. Moreover, these characteristics of the vibration may stimulate muscle spindles to fire at a rate approximately corresponding to that of motor units during maximal muscle contraction [4]. Cheng Wu [7] reported that the maximum rate of force development and performance in the blocking agility test significantly improved in volleyball players after being exposed to only one minute of WBV (30 Hz, 2 mm amplitude, 120° knee flexion) during warm-up. Adams et al. [5] reported that an acute bout of WBV led to a significant increase in muscle power,

with the highest power output occurring one minute after WBV administration and improvements in the performance lasting up to five minutes. Also, Cormie et al. [8] reported a significant increase in CMJ height immediately after 30 s of exposure to low frequency and low amplitude (30 Hz, displacement 2.5 mm) WBV. In contrast with these findings, Greco et al. [9] reported that following five consecutive bouts of 60 s of WBV (30 Hz, amplitude 3.9 mm) interspersed with 60 s rest, isometric mean force output was significantly lower after WBV than after the control condition. Although the exact mechanisms generating these responses to acute WBV are not fully understood yet, several potential mechanisms have been proposed ([5]; for a comprehensive review, see [3]). Among these mechanisms, the tonic vibration reflex (TVR) has been proposed as one of the main contributors to muscle strength and power gains. Indeed, WBV can elicit a reflex muscle contraction that activates muscle spindles, causing changes in the length and contraction speed of skeletal muscle fibers. Those changes would lead to an increased stretch–reflex loop, which, in turn, leads to an enhanced neuromuscular performance [6]. Furthermore, WBV may induce changes in the length and tone of the muscle–tendon complex, which can be detected by the sensory receptors that modulate muscle stiffness [6], thus leading to increased storage of elastic energy that may result in an improved jumping performance [10]. Muscle stiffness is a biomechanical property of the muscles defined as the capability of muscle tissue to resist deformation [11] when an external force is applied to it [12], and it represents the sum of muscle–tendon visco-elastic properties [12]. It could be hypothesized that exposure to WBV may influence muscle stiffness and that this latter may contribute to an increase in vertical jump performance. A very recent study [12] investigated the effects of chronic WBV on muscle stiffness and muscle performance, but no effect of WBV was observed on either variable. However, in that study, muscle performance was assessed using a maximal isometric strength test that has been previously claimed as poorly sensitive to WBV [9]; as a consequence, little or no information may be gained on the influence of WBV on muscle power. Moreover, in that study, the mechanical properties of the rectus femoris were collected, assuming that this muscle is representative of the whole quadriceps muscle. However, a very recent study [13] showed that the rectus femoris contributes minimally, compared to the vastus lateralis, to the performance of an unweighted squat, therefore resulting poorly targeted by the exposure of WBV. These methodological issues limit the knowledge of the mechanisms through which WBV may enhance muscle power. Moreover, evidence is lacking concerning the possible contribution of WBV-related increase in muscle stiffness to vertical jump performance. This information could be useful to support the previously mentioned hypothesis on the mechanisms through which WBV may ameliorate vertical jump performance.

Therefore, the aim of the present study is to assess whether (a) acute exposure to WBV may influence knee extensors muscle stiffness and (b) verify whether possible WBV-induced modifications in muscle stiffness are associated with increases in vertical jump performance of the countermovement jump (CMJ). Based on previous investigations, we expect that exposure to WBV would result in increased muscle stiffness and that this latter may be associated with an increase in CMJ performance.

2. Materials and Methods

2.1. Study Design

This interventional study adopted a randomized repeated-measure design. Participants attended one pre-testing session and two testing sessions in the Physical Exercise and Sports Science Laboratory at the University of “Magna Græcia”, Catanzaro. During the pre-testing session, experimental procedures were carefully explained to participants, and anthropometric variables, body composition, leg and foot length, and physical activity levels were measured. Afterward, participants underwent a preliminary test session to get acquainted with the experimental protocol. In the testing sessions, participants’ stiffness, assessed via the Wartenberg pendulum test, and CMJ performance were evaluated before (PRE) and after (POST), performing an isometric semi-squat. On separate days and in

randomized order, the isometric semi-squat was performed in two different conditions: semi-squat plus WBV (WBV) and semi-squat without WBV (CC). In both experimental conditions (WBV or CC), the pendulum test was performed immediately after the end of the semi-squat (within one minute). To avoid possible effects of fatigue and muscle soreness, each testing condition was interspersed by 48 h of rest, instructing participants to refrain from any type of physical activity the day before each testing session and avoid caffeine consumption two hour before the assessments. A schematic representation of the experimental protocol is reported in Figure 1. After a careful explanation of the test procedures, risks, and benefits, participants signed a written informed consent approved by the Ethical Committee of Regione Calabria (n°56/2023).

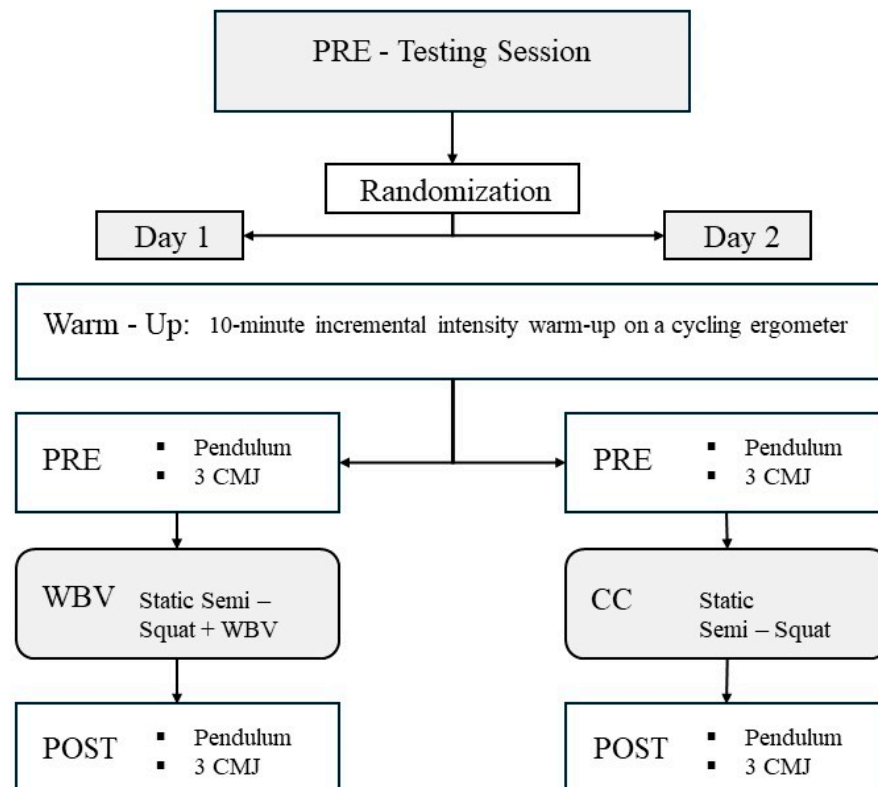


Figure 1. Schematic representation of the experimental protocol adopted in the present study. WBV—whole-body vibration; CC—control condition; CMJ—countermovement jump.

2.2. Participants

Thirty-three male university students were recruited, but only twenty-four of them were able to perform both the pendulum test and the CMJ (mean $\pm$ standard deviation (SD): age = 25.1 ± 3.3 years; BMI = 24.6 ± 3.3 kg/m²). An a-priori sample size calculation showed that twenty-two participants were sufficient to achieve a statistical power of 0.9 ($1-\beta = 0.9$; effect size = 0.3; $\alpha = 0.05$). All participants were asked to provide a medical certification stating their eligibility to perform non-competitive sporting activity. Participants were included in the study if they were males, aged 23–35 years old, weighed 65–85 kg, and reported no osteoarticular injuries in the six months preceding the test. Exclusion criteria included any contraindication to physical activity like the presence of acute thromboses, acute inflammations, acute tendinopathies, reported osteoarticular injuries or fractures in the six months preceding the testing session, musculoskeletal disorders and chronic disorders that exclude vibratory stimulation. Participants' characteristics involved in the study are shown in Table 1.

Table 1. Anthropometric and body composition characteristics of the sample.

Participants' Characteristics	
N°	24
Age [years]	25.1 ± 3.3
Height [m]	1.76 ± 0.10
Body Mass [kg]	74.7 ± 6.7
BMI [kg/m ²]	24.6 ± 3.3
% FM [%]	17.4 ± 5.1
SMM [kg]	34.6 ± 2.9
PAL [METs-min/week]	1693.0 ± 1629.3

Acronyms: N°—Number of participants; BMI—body mass index; % FM—fat mass percentage; SMM—skeletal muscle mass; PAL—physical activity level.

2.3. Experimental Protocol

During the pre-testing session, body mass and height were measured using a scale and a Harpenden stadiometer to the nearest 0.1 kg and 0.01 m, respectively. Body composition was measured using a bioelectrical impedance system (BIA ACCUNIQ 360, Daejeon, Republic of Korea) while participants wore minimal clothing. Physical activity levels were assessed using the Global Physical Activity Questionnaire (G-PAQ [14]). Afterward, participants were instructed on the technical execution of the CMJ and pendulum test and were allowed to perform ten practice trials for each test. Each testing session began with a 10-min incremental intensity warm-up performed on a cycling ergometer (Ergoselect, ergoline GmbH, Bitz, Germany). The intensity of the warm-up was kept within 60–70% of the estimated maximal heart rate (HR; 220—age; [15]). Warm-up consisted of three steps: 3 min at 50 watts, 3 min at 75 watts, and 4 min at 75 or 100 watts, according to the participant's HR. Participants' HR was continuously monitored using an HR monitor (Forerunner® 45, Garmin, Olathe, KS, USA). Individual perceived exertion during warm-up was evaluated using a 0–10 range scale where 0 corresponds to very light effort, and 10 corresponds to extremely intense (cycle ergometer Omni Scale; [16]). After the warm-up, participants were asked to perform the pendulum test according to Wartenberg's [17] instructions. In brief, participants sat on the edge of a table with their legs hanging freely. The Wartenberg pendulum test was conducted on the dominant lower limb with participants barefoot. The examiner lifted the participant's dominant limb to full knee extension and released it unpredictably after a few seconds. Upon release, participants were instructed to relax their knee extensor muscles, letting their leg swing passively until it stopped at the resting position. Before and after each experimental condition, participants performed a single attempt of the Wartenberg pendulum test. A tri-axial inertial measurement unit (IMU; G-SENSOR 2, BTS S.p.A, Padova, Italy; sampling frequency: 200 Hz; full scale: ±2 g; 2000°/s for the accelerometer and gyroscope, respectively) was employed to record angular velocity and linear acceleration at a sampling frequency of 200 Hz. The IMU was firmly attached to the participant's lower leg, immediately above the lateral malleolus, via elastic and adhesive straps. Side-view video recordings of the pendulum test were carried out for each trial and condition.

Immediately after the pendulum test, participants performed three maximal CMJs with shoes on. Starting from a standing position and performing a crouching action immediately followed by a jump for maximal height [18]. Participants were asked to maintain their hands on their hips throughout the entire movement, and each trial was interspersed by thirty seconds of rest. For each jump, height was recorded by using a tri-axial inertial measurement unit (Sensorize, FreePower, Rome, Italy) firmly attached to the participant's lower back, approximately over L4-L5 vertebrae, using elastic and adhesive straps. Then, after removing their shoes, participants stood on a Pro evolve vibrating platform (DKN, USA) in a static semi-squat position (130° of knee flexion with 180° representing knee full extension) for sixty seconds. Knee flexion angle was measured using a goniometer, and the participants' posture was visually monitored continuously. In the control condition (CC), no vibration stimuli were delivered, whereas in the whole-

body vibration (WBV), the platform was set at a median vibration frequency of 40 Hz ($g = 2.65 \text{ m/s}^2$, horizontal displacement = 0.527 mm, vertical amplitude = 3.9 mm). After the CC and WBV conditions, the pendulum test and the CMJ were repeated. At the end of each testing session, participants were instructed to perform lower limb stretching exercises.

2.4. Data Analysis

2.4.1. Wartenberg Pendulum Test

The angular velocity about the medio-lateral axis of the IMU attached to the participants' lower leg was used to compute the variables of interest for the Wartenberg pendulum test. In particular, the angular velocity recorded about the mediolateral axis of the sensor was filtered using a zero-lag second-order Butterworth filter with a cut-off frequency of 5 Hz [19] and integrated to compute the knee flexion–extension angle about the mediolateral axis.

Knee flexion–extension angle about the mediolateral axis was used to compute the damping and the stiffness coefficients, as detailed in Casabona et al. [19]. Briefly, the damping coefficient (B) was estimated by computing the damping ratio (ζ) and the natural frequency (ω) obtained for each trial as follows:

$$\zeta = \sqrt{\frac{(\ln D)^2}{4\pi^2 + (\ln D)^2}} \quad (1)$$

where $D = \theta_1/\theta_2$ and θ_1 represents the peak knee flexion of the first cycle, and θ_2 is the peak knee flexion of the second cycle. The natural frequency (ω) was obtained by dividing $2\pi/T$ with T representing the period of the pendulum.

Using these equations, the damping coefficient (B) was computed as follows:

$$B = 2 \cdot \zeta \cdot \omega \cdot J \quad (2)$$

where J corresponds to the moment of inertia of the leg–foot complex computed about the mediolateral axis of the knee joint. The estimation of body segment mass, center of mass position, and inertia parameters about the transverse plane of the leg and foot were computed from De Leva et al. [20]. Last, the stiffness coefficient (K) was computed using the following equation:

$$K = J \cdot \omega^2 \quad (3)$$

Typical examples of knee angular velocity and knee flexion–extension angle from a representative participant are reported in Figure 2. To provide a comprehensive description of the execution of the Wartenberg pendulum test across conditions, maximal knee flexion angle (θ_{Peak}) and maximal knee flexion angular velocity (ω_{Peak}) were computed from knee flexion–extension angle and from knee angular velocity about the mediolateral axis of the knee.

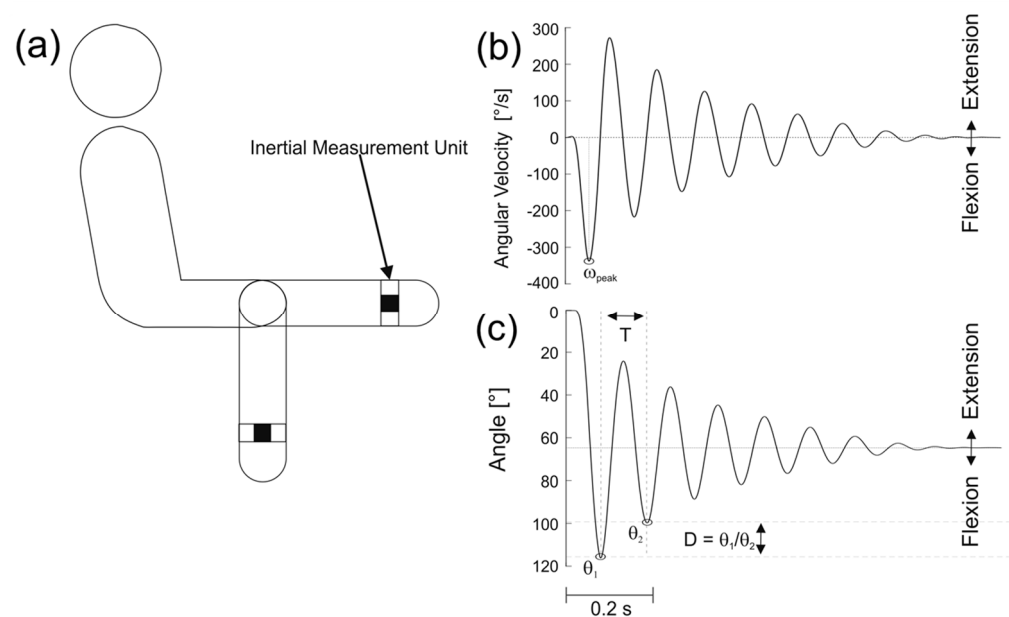


Figure 2. (a) Participants' positioning for the Wartenberg pendulum test. (b) Knee angular velocity and (c) knee flexion–extension angle from a representative participant. Positive values represent knee flexion. Acronyms: T—pendulum period; ω_{Peak} —peak knee flexion angular velocity; θ_1 —knee flexion angle of the first cycle; θ_2 —knee flexion angle of the second cycle.

2.4.2. Countermovement Jump

For the CMJ, the mean value across the three trials was computed. This method has shown to produce more reliable data compared to the analysis of the best attempt [21].

2.5. Statistical Analysis

All the statistical analyses detailed in the following paragraph have been conducted using IBM® SPSS statistical software version 20.0 (SPSS Inc., IBM, Chicago, IL, USA). For all statistical tests, the null hypothesis has been rejected with $p < 0.05$. All variables were tested for normal distribution using the Shapiro–Wilk test. All variables had a normal distribution and have been expressed as the mean and standard deviation in tables and figures.

To verify whether the standardized warm-up had similar effects on the participants between the two conditions, HR_{mean} and Omni Scale cycling perceived exertion were submitted to separate paired t -tests.

To assess the effect of WBV protocol on Wartenberg pendulum test variables (θ_{Peak} ; ω_{Peak} ; B; T and K) a repeated measure analysis of variance (RM-ANOVA) was carried out with time of assessment (PRE; POST) and condition (WBV; CC) as repeated factors. The same statistical approach was used to test the effect of the whole-body vibration protocol on CMJ height. When significant main effects were observed, pairwise comparisons were carried out. Bonferroni–Holm correction was applied to control for multiple comparisons. To investigate the presence of a relationship between stiffness and jump performance, Pearson's product–moment correlations were carried out between changes across time (PRE vs. POST) in K (ΔK) and changes in CMJ height (ΔCMJ) separately for the CC and WBV conditions.

3. Results

The standardized warm-up elicited the same responses in the participants' HR_{mean} and in the Omni scale. In both conditions, participants warmed up at an average power output of 74.0 ± 2.8 Watts. This warm-up intensity resulted in a HR_{mean} of 114.0 ± 14.2 bpm for the WBV condition and 116.1 ± 13.0 bpm for the CC condition. No difference in HR_{mean} was observed between the warm-ups performed prior to WBV or CC ($p = 0.262$). The Omni

Scale cycling perceived exertion during the warm-up was 3.6 ± 1.0 and 3.5 ± 1.2 for WBV and CC conditions, respectively ($p = 0.80$).

3.1. Wartenberg Pendulum Test

The results of the variables computed for the pendulum test are reported in Table 2. The RM-ANOVA performed on maximal knee flexion angle (θ_{Peak}) yielded no significant main effect of condition ($F_{1,23} = 0.004$; $p = 0.951$; $\eta^2 < 0.001$), time ($F_{1,23} = 0.782$; $p = 0.386$; $\eta^2 = 0.033$) or interaction ($F_{1,23} = 0.691$; $p = 0.414$; $\eta^2 = 0.029$). Similarly, no effect of condition ($F_{1,23} = 0.001$; $p = 0.983$; $\eta^2 < 0.001$), time ($F_{1,23} = 0.755$; $p = 0.394$; $\eta^2 = 0.032$) or interaction ($F_{1,23} = 0.164$; $p = 0.689$; $\eta^2 = 0.007$) was observed for maximal knee flexion angular velocity (ω_{Peak}). A significant main effect of time was observed for the damping coefficient ($F_{1,23} = 4.553$; $p = 0.044$; $\eta^2 = 0.165$). The Bonferroni–Holm corrected pairwise comparisons showed that the damping coefficient increased after the static squat, either with or without the exposure to WBV. No significant effect of condition ($F_{1,23} = 0.914$; $p = 0.349$; $\eta^2 = 0.038$) and no significant interaction ($F_{1,23} = 0.006$; $p = 0.941$; $\eta^2 < 0.001$) was observed for this variable. The RM-ANOVA carried out on the period of Wartenberg’s test showed a significant condition by time interaction ($F_{1,23} = 4.615$; $p = 0.042$; $\eta^2 = 0.176$). The Bonferroni–Holm corrected pairwise comparisons showed that the pendulums’ period was significantly shorter after the exposure to the static squat in the CC condition only ($p = 0.010$). No significant effect of condition ($F_{1,23} = 0.463$; $p = 0.503$; $\eta^2 = 0.020$) and time was observed ($F_{1,23} = 3.850$; $p = 0.062$; $\eta^2 = 0.143$).

Table 2. Countermovement jump height (CMJ) and kinematic variables of the pendulum test. θ_{Peak} —maximal knee flexion angle; ω_{Peak} —maximal knee flexion angular velocity.

		Pre		Post	
		CC	WBV	CC	WBV
CMJ	[m]	0.42 ± 0.05	0.43 ± 0.05	0.43 ± 0.05	0.42 ± 0.05
θ_{Peak}	[°]	104.5 ± 10.1	103.5 ± 11.7	102.6 ± 12.1	103.8 ± 10.6
ω_{Peak}	[°/s]	299.7 ± 39.5	297.7 ± 50.8	294.5 ± 44.5	296.2 ± 39.0
Period	[s]	1.022 ± 0.043	1.020 ± 0.045	$1.013 \pm 0.038^*$	1.019 ± 0.043
Damping Coef #	[Nm/s/rad]	0.056 ± 0.019	0.053 ± 0.019	0.061 ± 0.017	0.058 ± 0.019
Stiffness Coef	[Nm/rad]	7.22 ± 1.37	7.20 ± 1.37	$7.09 \pm 1.28^*$	7.18 ± 1.36

Period—pendulum period; CC—control condition; WBV—whole-body vibration. * denotes a significant difference from the pre-intervention assessment. # denotes a significant main effect of time of assessment.

A significant interaction effect was observed for the stiffness coefficient ($F_{1,23} = 5.652$; $p = 0.026$; $\eta^2 = 0.197$). The Bonferroni–Holm corrected pairwise comparisons showed that the stiffness coefficient decreased significantly after exposure to the static squat condition ($p = 0.006$). Conversely, no difference was observed after the exposure to WBV ($p = 0.599$). A significant main effect of time was observed for this variable ($F_{1,23} = 4.408$; $p = 0.047$; $\eta^2 = 0.161$). The pairwise comparisons showed that the stiffness coefficient was reduced ($p = 0.047$) after the static squat when participants were exposed to either WBV or CC. No significant main effect of condition was observed for this variable ($F_{1,23} = 0.486$; $p = 0.493$; $\eta^2 = 0.021$).

3.2. Countermovement Jump

The RM-ANOVA performed on CMJ height showed no significant effect of condition ($F_{1,23} = 0.283$; $p = 0.600$; $\eta^2 = 0.012$), time ($F_{1,23} = 0.319$; $p = 0.578$; $\eta^2 = 0.014$) and no condition by time interaction ($F_{1,23} = 2.424$; $p = 0.133$; $\eta^2 = 0.095$; Table 2).

Pearson’s product–moment correlations carried out between changes in CMJ height (ΔCMJ) and changes in stiffness (ΔK) were not significant ($p = 0.244$ and $p = 0.202$ for WBV and CC, respectively).

4. Discussion

The aim of this study was to investigate the effect of whole-body vibration on muscle stiffness and to assess whether changes in muscle stiffness may account for changes in CMJ height. We hypothesized that improvements in CMJ height after exposure to WBV may be associated with increased muscle stiffness. Contrary to our initial hypothesis, the exposure to WBV had no effect on knee extensor passive muscle stiffness. Conversely, a reduction in knee extensor passive muscle stiffness from PRE to POST intervention assessments was observed in CC. Notwithstanding these differences in muscle stiffness, no effect was observed on CMJ height both after WBV or CC. Additionally, no significant correlations were observed between changes in CMJ height (ΔCMJ) and changes in muscle stiffness (ΔK).

Previous studies showed enhanced jump height after acute exposure to whole-body vibration [1,5,6]. However, in our study, no changes in CMJ height were observed. These controversial results could be ascribed to different factors. First, the greater part of the studies focused on chronic exposure to WBV [5] (for reviews, see [1,6]), whereas, in our study, only an acute bout of WBV was administered. Second, the acute WBV protocol adopted in the present study may not have been sufficiently intense to elicit improvements in jump height. A previous study showed an increased CMJ height after one-minute exposure to WBV [22]; however, in that study, an oscillating platform was employed to deliver the vibrating stimulus with a frequency of 26 Hz. These differences in the typology and frequency of vibration stimuli may account for the discrepancy between the results of the study of Cochrane and Stannard [22] and ours. However, it must be noted that the vibration frequency adopted in our study seems to be most suitable for eliciting improvements in CMJ height [23]. Indeed, Turner et al. [23] showed that 30 s exposure to WBV on a vertical vibrating platform at 40 Hz resulted in an increased CMJ height.

Previous studies [6] posited that exposure to WBV had the potential to increase muscle stiffness and performance through the mechanically evoked stimulation of muscle spindles; this, in turn, would increase the storage of elastic energy and enable participants to increase jump height. However, in our study, no significant effect of WBV was observed on the stiffness of knee extensor muscles, whereas a significant reduction in muscle stiffness was observed after the static squat condition (CC). This result is in keeping with Cronin and colleagues [24]. Indeed, in that study, they showed a decrease in muscle stiffness in the control limb as compared to a slight, yet not significant, increase in the stiffness of the triceps surae in the WBV-exposed limb. Our results are in line with previous studies on the effects of WBV on muscle stiffness [24–27]. However, these studies focused on muscle stiffness of different lower limb muscles or evaluating the stiffness of the whole lower limb (vertical stiffness). Cronin et al. [24] focused on triceps surae muscle stiffness after acute exposure to WBV while participants were flat-footed in a semi-squat position. Possibly due to foot positioning, the exposure to WBV may have had little influence on triceps surae stiffness in that study. Similarly, in the study of Roschel et al. [25], no effect of WBV combined with resistance training was observed on vertical stiffness. Interestingly, participants in that study were exposed to WBV for six weeks. Similarly, another study [26] did not show differences in lower limb vertical stiffness following five minutes of exposure to WBV. However, these latter studies investigated vertical stiffness using an in-place hopping test, thus evaluating muscle stiffness of the whole limb. Conversely, in the study of Siu et al. [27] and that of Basol et al. [12], the authors used specific instruments to evaluate the effects of WBV on muscle stiffness of knee extensors and flexors. However, when single muscle groups were investigated, neither study reported any beneficial effects on muscle stiffness [12,27].

In parallel with these results on CMJ and muscle stiffness, we observed no significant correlation between changes in CMJ height (ΔCMJ) and changes in muscle stiffness (ΔK). This result stands for little or no contribution of muscle stiffness to possible improvements in CMJ following acute WBV. Thus, other factors should be accounted for the improved CMJ height at least following an acute bout of WBV.

As a final remark, a relatively large number of participants (9 out of 33 participants; 26%) had to be excluded from the study as they were not able to correctly perform the pendulum test or the CMJ. Most of these participants were unable to fully relax their knee extensor muscles when their limb was unpredictably released during the Wartenberg pendulum test.

This study suffers from some limitations that should be acknowledged to safely interpret the present results. First, no information on muscle activation during the oscillations was collected. This information would have enabled participants to improve their ability to relax their limbs through a biofeedback mechanism and allow a larger number of participants to be included in the study. Moreover, it would have enabled us to discard trials where participants were not sufficiently relaxed prior to limb release. It is worth mentioning that if any activation of the knee extensor muscle occurred immediately after the unpredictable release of the limb, a modification of knee angular velocity would have been observed. Indeed, before data analysis, all trials were visually inspected to discard trials showing altered kinematics. Similarly, it has to be noted that the equations used to compute the damping and stiffness coefficients hold only for movements occurring about a single degree of freedom joint. The video-recorded trials of the pendulum test were checked to ascertain the accuracy of the execution prior to further analysis. Another limitation of this study is that our results cannot be safely generalized to the whole population since our sample was composed only of young males.

Future studies are warranted to delve into the possible mechanisms through which WBV influences muscle power, especially focusing on motor unit recruitment and on the descending volleys from motor areas of the central nervous system in participants exposed to chronic WBV training regimens and if these mechanisms also hold in females.

5. Conclusions

The exposure to the whole-body vibration protocol adopted in our study did not affect passive muscle stiffness and countermovement jump height. However, with the current protocol, the exposure to whole-body vibration resulted in a limited reduction in passive stiffness compared to what was observed after a static squat. Future studies shall investigate whether a dose–response relationship exists between whole-body vibration and passive muscle stiffness and the benefits in terms of jumping performance.

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Data Availability Statement: The dataset will be made available upon request.

Conflicts of Interest: The authors declare no conflicts of interest.

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