The Acute Effects of Whole Body Vibration on Isometric Mid-Thigh Pull Performance

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Abstract: The purpose of the present investigation was to examine the acute effects of whole body vibration (WBV) on isometric mid-thigh pull force–time curve (FTC) characteristics. Eleven recreationally trained subjects were randomly assigned to three treatment conditions: sham no vibration protocol (T1), vibration protocol 30 Hz 2–4 mm amplitude (T2), and vibration protocol 30 Hz 2–4 mm (T3). After completing a standardized warm-up, the subject stood on a vibration platform with the knee at a 120° angle and performed one of the three interventions. Each treatment condition required the subject to stand on the platform for thirty-second treatments, each separated by thirty seconds of recovery. Five minutes after the completion of the treatment conditions, the subjects performed the isometric mid-thigh pull. All FTCs were analyzed with standardized procedures for peak force (PF) and peak rate of force development (PRFD). A 1×3 repeated measures analysis of variance (ANOVA) was used to compare the three treatments. Additionally, coefficients of variance (CV), as well as intraclass and interclass correlations, were performed. There were no significant differences ($p > 0.05$) for any of the FTC analyses performed in this investigation. The CV and the 95% confidence interval (CI) indicate that the WBV protocol resulted in trivial changes in PF and beneficial changes in PRFD. A 30 Hz 2–4 mm amplitude WBV does not result in a significant increase in isometric mid-thigh pull performance.

Keywords: force–time curve; rate of force development; peak force; strength

1. Introduction

The use of whole body vibration (WBV) as a method to enhance neuromuscular and strength-power performance has only recently begun to be explored by sport scientists [1–7]. Specifically, WBV training has been shown to improve countermovement vertical jump performance over 3–4 months versus resistance training alone in previously untrained and older men and women [8–11]. Additionally, acute exposure to WBV has been suggested to produce transient increases in force production [12–14], vertical jump displacement [1,7,13], and power output [7,12,15,16] recorded while performing various ballistic and non-ballistic tasks. On the basis of these transient responses, it has been suggested that WBV could be an affective pre-activity warm-up practice [1,17].

It has been hypothesized that the reported acute WBV-induced increases in performance occur as a result of alterations in neuromuscular stimulation, namely reflex potentiation (RP) and post

activation potentiation (PAP) [1,4,18]. Such alterations have been suggested to reside in motor unit, recruitment, and synchronization, as well as increased sensory input resulting in improvements in force generation and enhanced proprioception [19]. Specifically, most studies have ascribed the observed improvements to the likelihood of WBV producing a "tonic vibration reflex" (TVR) in which a moderate level of force is produced, and then maintained following an initial high phasic discharge from primary Ia muscle spindle afferents. The resultant motor response evoked is thought to result in the excitation of the alpha-motor neurons innervating extrafusal fibers [1]. This response may lead to a greater synchronization of motor units as a result of homonymous motor unit contraction [19,20]. Support for this contention has been found in the vibration-induced shifts in electromyography (EMG) pattern during direct application to a muscle [19,21,22]. Overall, the response of the TVR is dictated by the frequency and amplitude of the WBV stimulus, as well as body alignment in relation to the plate [2,20,23–25]. During WBV exposure, the stretch rand Hoffman-reflex's (H-reflex) are both initially inhibited via pre-synaptic inhibition, while sensory information from other key mechanoreceptors induces a TVR [20,26]. Collectively the occurrence of these three WBV-induced responses is termed the "vibration paradox" [20]. The H-reflex has been shown to be depressed to a greater extent than the stretch-reflex and takes longer to recover [3,27,28]. The stretch-reflex appears to be initially depressed, but then may experience potentiation [20]. The frequency, amplitude, and duration of application of the WBV stimulus appear to affect the rate of recovery seen in those of the stretch and H-reflex [1,2,9–11,28,29].

Vibration is an oscillatory motion characterized by a frequency and peak–peak amplitude. Optimal vibration protocols are not well established in the scientific literature. However, there seems to be a consensus in the literature indicating that a WBV frequency as low as 30 Hz may lead to acute enhancements in strength-power performance in the lower limbs [2,19]. Cardinale and Lim [19] reported that the highest reflex activation of muscles within the quadriceps femoris, as indicated by EMGrms data, occurs within the Vastus Lateralis while squatting statically on a WBV platform oscillating at 30 Hz. Collectively, the literature appears to suggest that strength and power performance of the lower limbs can be acutely enhanced with the use of a 30 Hz frequency [2,13,14,19,23].

While some acute performance responses to WBV support these suggested mechanistic responses, not all investigations report improvements in muscular force [1,17], vertical jump [15], and power production in response to acute WBV [1,17]. For example, Cormie et al. [1] examined the effects of WBV on performance during an isometric squat and found no significant improvement in peak force following 30 s of a 30 Hz and 2.5 mm amplitude WBV stimulus. Interestingly, while not statistically significant, there appeared to be less of a decline in isometric peak force as a result of fatigue generated at 5 and 15 min post-WBV. While these data may suggest a trend toward enhancement of the isometric force–time curve, no data were reported on other force–time curve characteristics such as the rate of force development (RFD). de Ruiter et al. [30] reported the RFD achieved during a maximal volitional contraction (MVC) knee extension was unaffected by WBV applied at 30 Hz and 8 mm peak–peak amplitude for five bouts of one minute. While this finding is interesting, it may be warranted to evaluate the isometric force–time curve using multi-joint isometric muscle actions such as the isometric mid-thigh pull. To date, only one study has attempted to elucidate relationships between acute WBV and performance during an isometric mid-thigh pull and reported no significant differences in RFD or ground reaction forces [17]. However, those authors compared five different warm-up protocols, all completed on the same day, to determine if there were differences between dynamic and isometric warm-ups, both with and without vibration, after which subjects would complete the isometric mid-thigh pull assessment. Owing to the various layers of interactions in this study design being conducted on only fifteen subjects and the potential for fatigue manifestation affecting the results, further study on WBV and isometric mid-thigh pull performance is warranted. A comparison of data collected during an isometric muscle action with those observed in dynamic muscle actions is dictated by the similarity of the activity to the dynamic muscle action [27]. Because RFD is considered to be an important factor underlying the expression of explosive strength [8,14,31], it is imperative that

further investigation into the acute effects of WBV on this important force–time curve characteristic be performed.

It is possible that acute WBV exposure may result in alterations to specific aspects of the force–time curve during the performance of a ramp maximal isometric contraction. Therefore, the primary purpose of this investigation was to examine the acute effects of WBV administered using a 30 Hz and 2–4 mm amplitude during isometric body weight squats upon subsequent force–time characteristics recorded during an isometric mid-thigh pull.

2. Methods

Experimental Approach to the Problem: The present study was designed to investigate the effects of whole body vibration (WBV) on isometric mid-thigh pull force–time curve characteristics. Each subject went through four testing sessions that consisted of a preliminary/familiarization testing session and three testing sessions in which various treatment conditions were undertaken. The three random ordered testing sessions were each separated by seven days (Figure 1). During each testing session, the subjects underwent a standardized warm-up protocol, which was followed by one of the three treatment conditions. Treatment condition 1 (T1) was an isometric pull-sham treatment, while treatment conditions 2 (T2) and 3 (T3) were isometric pull vibration treatments. Five minutes after the sham or WBV treatments, the subject performed two maximal isometric mid-thigh pulls separated by 2 min. Athletes were instructed to avoid vigorous activity within 48 h of the testing session. A summary of the testing protocol can be found in Figure 2.

Subjects: Eleven (four women and seven men) recreationally trained individuals served as subjects in the present investigation, which was approved by the East Tennessee State University Institutional Review Board (IRB). All subjects were actively engaged in resistance exercise for the previous 12 months, although not necessarily in a competitive manner. All subjects read and signed informed consent documents in accordance with the East Tennessee State IRB.

The first testing session was used to perform all preliminary testing. This testing included the collection of the subject's physical characteristics. A summary of the subject characteristics is presented in Table 1. Additionally, during this session, each subject was familiarized with the isometric mid-thigh pull testing procedures. Seven days after the completion of the familiarization session and 48 h after their last exercise bout, the subjects performed one of the three randomly assigned treatment conditions.
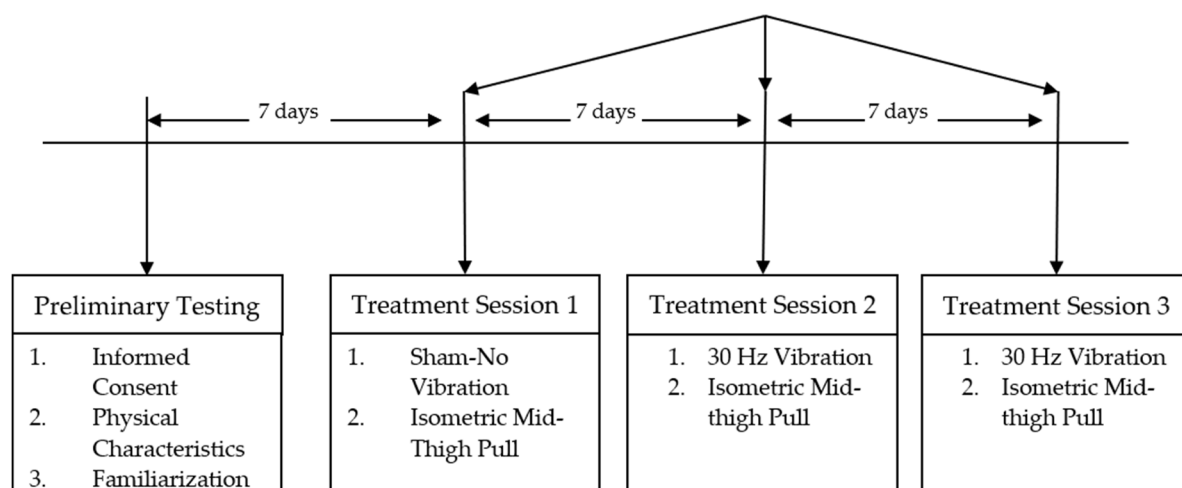

Figure 1. Testing timeline. * The sham could have occurred at T1, T2, or T3.

Testing Protocol: Hydration status was measured at the start of each testing session using a refractometer (ATOGO, Tokyo, Japan) to ensure that dehydration did not negatively impact testing. Prior to initiating the testing sessions, each subject performed a standardized warm-up protocol consisting of 20 jumping jacks, 5 mid-thigh pulls with a 20 kg (Werksan Barbell, Moorestown, NJ,

USA), and then 3 sets of 5 repetitions of mid-thigh pulls with either 40 kg (women) or 60 kg (men). Once the warm-up was completed, the subjects then performed one of the randomly assigned treatment conditions.
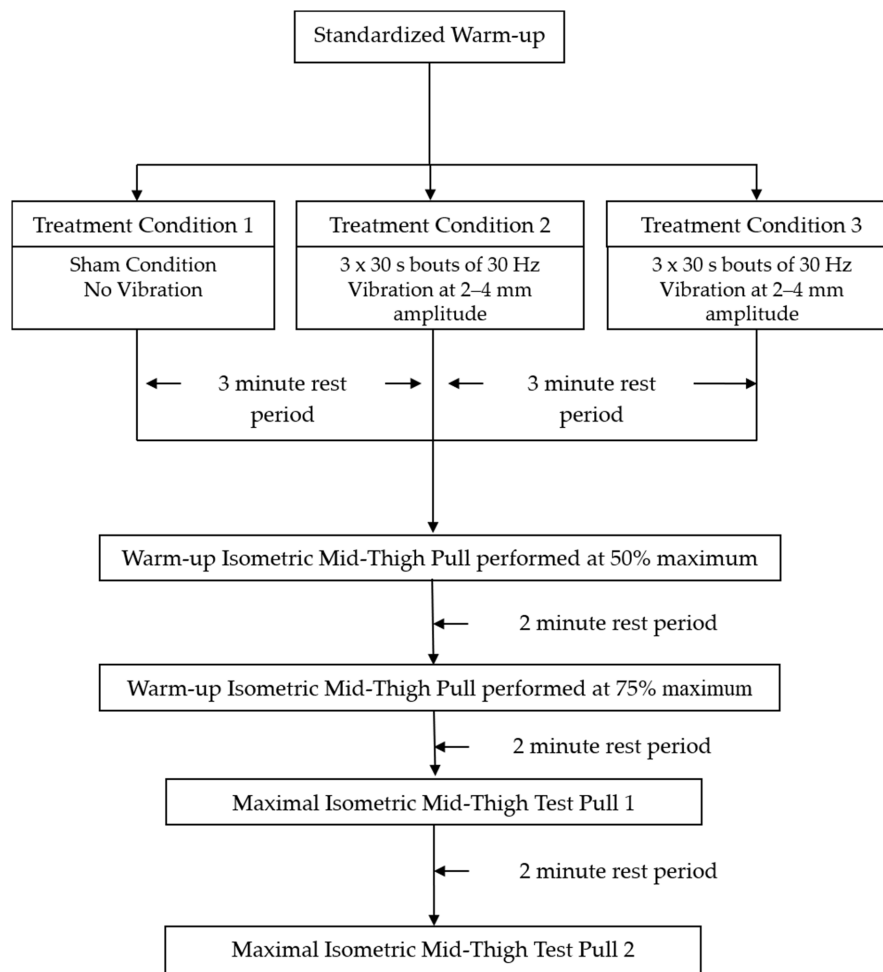
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                        ┌─────────────────────────┐
                        │   Standardized Warm-up   │
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Treatment Condition 1	Treatment Condition 2	Treatment Condition 3
Sham Condition No Vibration	3 x 30 s bouts of 30 Hz Vibration at 2–4 mm amplitude	3 x 30 s bouts of 30 Hz Vibration at 2–4 mm amplitude

← 3 minute rest period → ← 3 minute rest period →

Warm-up Isometric Mid-Thigh Pull performed at 50% maximum

← 2 minute rest period

Warm-up Isometric Mid-Thigh Pull performed at 75% maximum

← 2 minute rest period

Maximal Isometric Mid-Thigh Test Pull 1

← 2 minute rest period

Maximal Isometric Mid-Thigh Test Pull 2

Figure 2. Testing protocol.

Table 1. Subject physical characteristics (n = 11).

	Males (n = 7)	Females (n = 4)	Combined (n = 11)
	Mean ± SD	Mean ± SD	Mean ± SD
Age (y)	24.7 ± 1.8	23.5 ± 1.0	24.3 ± 1.6
Height (cm)	179.2 ± 6.2	164.8 ± 6.8	173.9 ± 9.5
Weight (kg)	101.7 ± 12.9	65.3 ± 5.2	88.4 ± 21.1

Treatment Condition 1: T1 was an isometric pull-sham treatment condition. In this condition, the subjects stood with a knee angle of 120° for thirty seconds on a WBV platform (Power Plate North America, Northbrook, IL, USA), which delivered no vibration. The subjects performed this treatment three times with 30 s of rest separating each trial. After the completion of the third trial, the subjects rested for 5 min and then performed the isometric mid-thigh pull protocol.

Treatment Condition 2 and 3: T2 and T3 consisted of a WBV protocol in which the subjects stood for 30 s with a knee angle of 120° on a vibrating platform (Power Plate North America, Northbrook, IL, USA), which oscillated in three planes (superior to inferior, medial to lateral, and anterior to posterior). A 30 Hz frequency with 2–4 mm amplitude was utilized as the WBV protocol based upon previously

published research [1,2,19,23]. A total of three bouts of vibration each separated by 30 s were performed by each subject during these sessions. Five minutes after the completion of the vibration protocol, the subjects performed the isometric mid-thigh pull protocol.

Isometric Mid-Thigh Pull Methods: All isometric mid-thigh pulls were performed on a custom isometric rack that allowed the bar to be fixed at any height above the floor and was placed over a force plate (Rice Lake, WI, USA), which sampled at 1000 Hz [27,29,32]. The subjects performed a total of four isometric mid-thigh pulls during this part of the testing protocol. The first two pulls were performed at 50% and 75% of perceived maximal effort and served as a warm-up, while the next two pulls were performed at maximal effort. A two-minute rest was given between each of the isometric pulls performed during this part of the test. If the two maximal isometric pulls were different by more than 250 N for peak force, a third trial was completed. For each pull, the subjects were told to "remain neutral on the bar . . . 3,2,1, pull!". The force–time curve generated by each isometric mid-thigh clean pull was recorded using a shielded BNC adaptor (BNC-2090, National Instruments, Austin, TX) and an A/D card (NI PCI-6014, National Instruments, Austin TX). The recording of all force–time curve data was performed with a 1000 Hz analogue to digital sampling rate using LabVIEW software (Version 8.5, National Instruments, Austin, TX, USA). Data were smoothed using a moving average.

Data Analysis: The analysis of all force–time curve data was performed with the use of a custom LabVIEW (Version 8.5, National Instruments, Austin, TX, USA) program and previously published methods [1,29,33]. The absolute peak force and peak forces at 50, 90, 200, and 250 ms were determined. Additionally, the RFD between 0 and 50 ms, 0 and 90 ms, 0 and 200 ms, and 0 and 250 ms was also quantified. In order to account for the effect of different body sizes in the present subject pool, all data were also allometrically scaled by applying the two-thirds power law: load × (body mass$^{0.67}$)$^{-1}$ [33]. Finally, percent differences were calculated between selected variables with the following formula:

$$\% \, Difference = \frac{(Vibration - Sham)}{Sham} \times 100$$

Statistical Analysis: All data from the present investigation are reported as means ± standard deviation (SD) and analyzed using SPSS (version 14.0, SPSS Inc., Chicago, IL). Multiple 1 × 3 (variable × treatment) repeated measures analyses of variance (ANOVA) with significance set at $p \leq 0.05$ was performed for all force–time curve variables analyzed. When significant F values were determined, follow-up paired comparisons were performed in conjunction with a Holm's Sequential Bonferroni in order to control for Type I errors [31]. Reliability of the measures performed was determined with the methods presented by Hopkins [34]. Additionally, coefficients of variance were calculated between the sham and vibration treatments (T1 and T2; T1 and T3) in order to determine if the vibration treatment resulted in a worthwhile enhancement in performance [35]. Pearson's product moment correlations were calculated to quantify relationships between percent differences in the tested measures and the subject's body mass.

Results: When assessing the reliability of the different measurements performed in the present study, it was determined that all variables were highly reliable, as indicated by high intraclass and interclass correlations performed between the two isometric mid-thigh clean pull trials performed under each condition (Table 2). Additionally, there were no statistically significant differences between any of the treatment groups for the force–time curve parameters analyzed ($p > 0.05$). A summary of these results can be found in Tables 3 and 4.

The results of the coefficient of variance, intraclass correlation, and interclass correlation analyses performed between the sham and vibration treatments (T1 vs. T2; T1 vs. T3) are presented in Table 4. Finally, the percent difference scores between the T1 versus T2 and T1 versus T3 are presented in Figures 3 and 4. There were no significant differences ($p > 0.05$) for the percent differences between the sham and vibration conditions for any of the force–time curve variables analyzed in the present investigation.
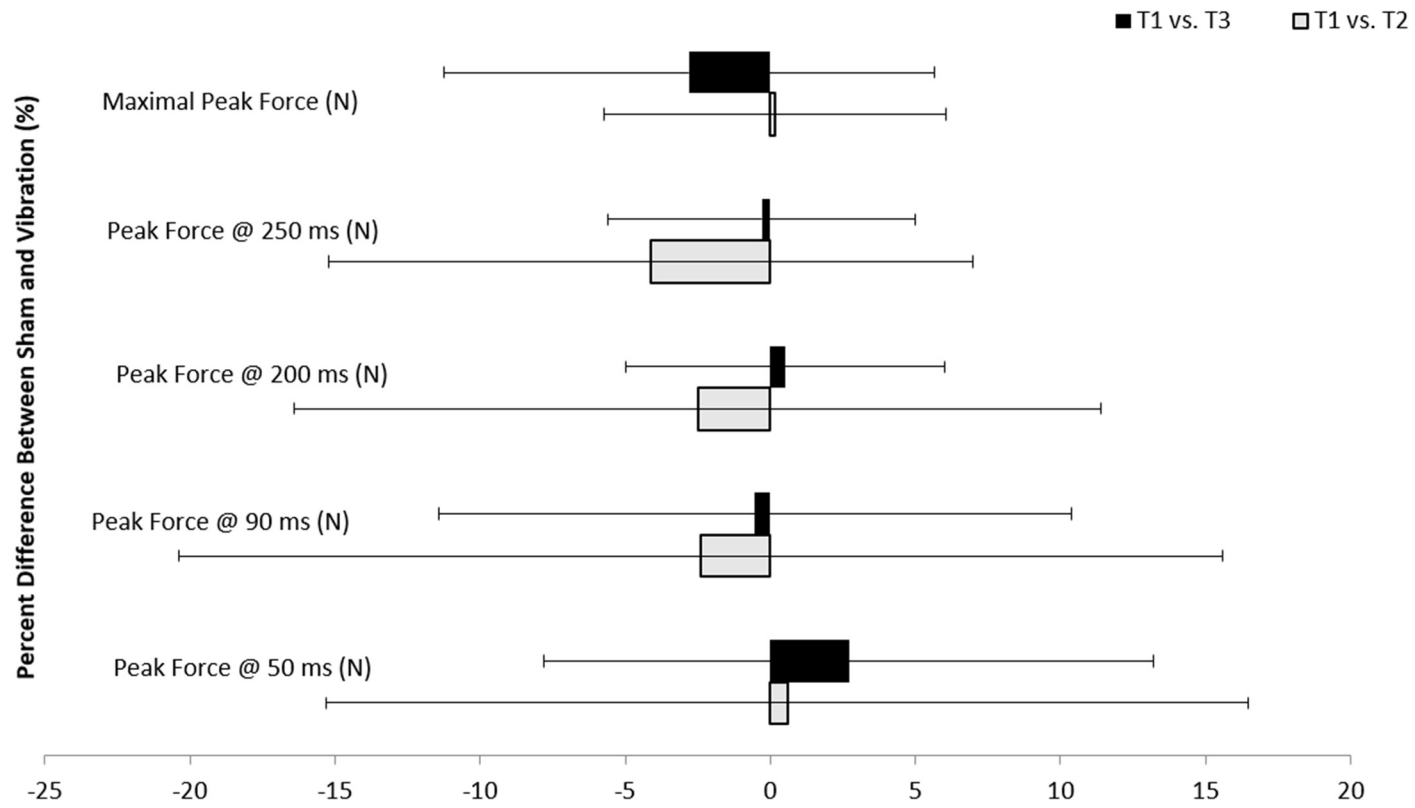
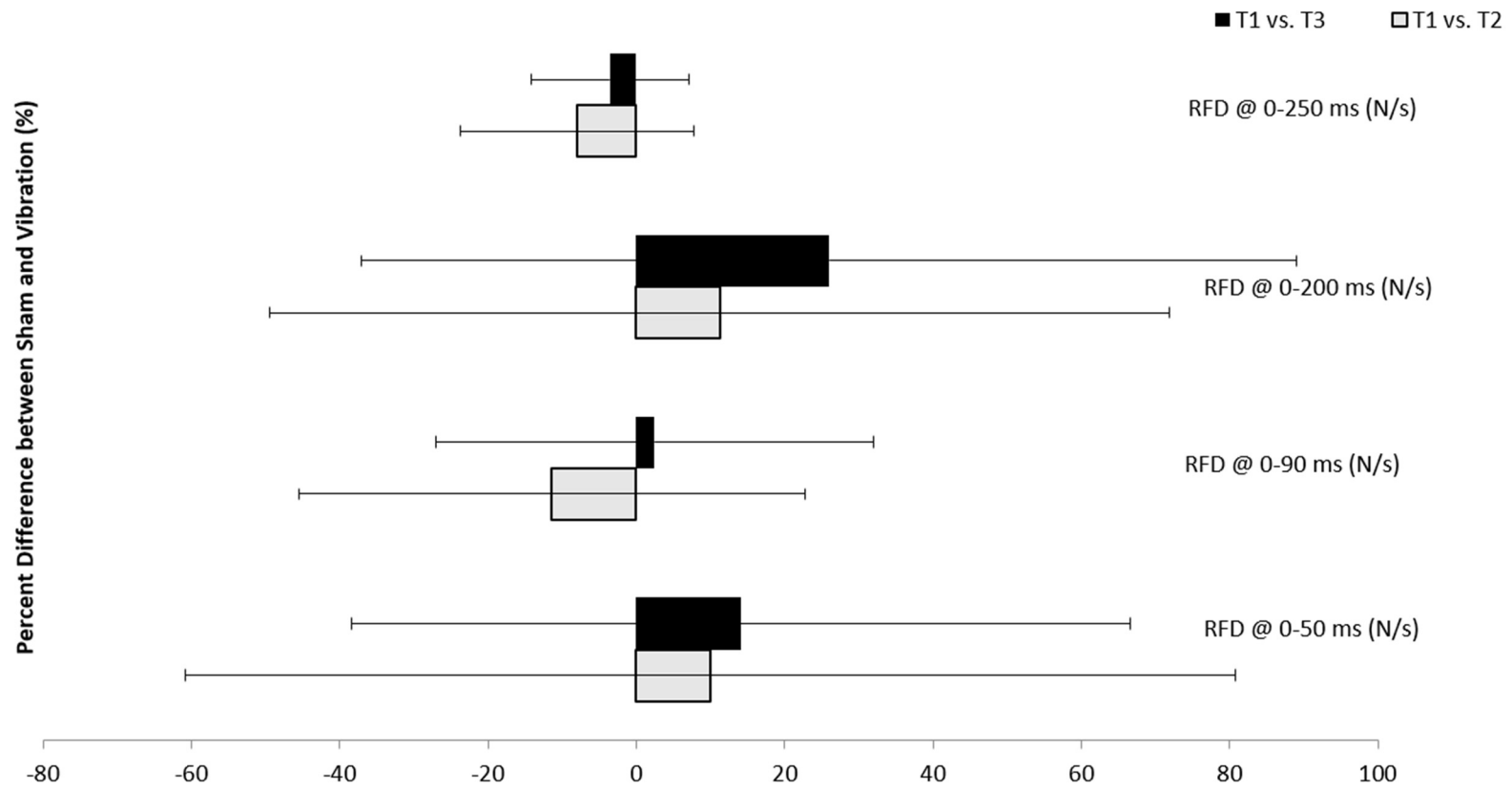**Figure 3.** Percent change for peak force between sham and vibration treatments.

Figure 4. Percent change for the peak rate of force development (RFD) between sham and vibration treatments.

Table 2. Reliability of force–time curve measurements.

	T1				T2				T3			
	ICCα	95% CI	R	95% CI	ICCα	95% CI	R	95% CI	ICCα	95% CI	R	95% CI
Peak Force @ 50 ms	0.96	0.87–0.98	0.95	0.85–0.98	0.94	0.83–0.98	0.94	0.83–0.95	0.94	0.84–0.98	0.94	0.81–0.98
Peak Force @ 90 ms	0.97	0.92–0.99	0.97	0.90–0.99	0.97	0.91–0.99	0.98	0.94–0.99	0.88	0.67–0.96	0.87	0.63–0.96
Peak Force @ 200 ms	0.98	0.95–0.99	0.98	0.93–0.99	0.93	0.80–0.98	0.93	0.80–0.98	0.96	0.89–0.99	0.96	0.87–0.99
Peak Force @ 250 ms	0.99	0.98–1.00	0.99	0.97–1.00	0.98	0.93–0.99	0.97	0.91–0.99	0.96	0.90–0.99	0.96	0.89–0.99
Maximal Peak Force	>0.99	0.99–1.00	1.00	0.99–1.00	>0.99	0.99–1.00	>0.99	0.99–1.00	>0.99	0.99–1.00	1.00	0.99–1.00
PRFD @ 0–50 ms	0.92	0.79–0.97	0.91	0.75–0.97	0.81	0.53–0.93	0.79	0.46–0.93	0.89	0.70–0.96	0.89	0.69–0.96
PRFD @ 0–90 ms	0.93	0.79–0.97	0.92	0.76–0.97	0.88	0.69–0.96	0.90	0.72–0.97	0.86	0.63–0.95	0.85	0.59–0.95
PRFD @ 0–200 ms	0.97	0.91–0.99	0.97	0.90–0.99	0.95	0.87–0.98	0.95	0.85–0.98	0.88	0.67–0.96	0.87	0.64–0.96
PRFD @ 0–250 ms	0.97	0.92–0.99	0.97	0.91–0.99	0.93	0.82–0.98	0.93	0.80–0.98	0.97	0.94–0.99	0.97	0.89–0.99

Note: ICCα = intraclass correlation; 95% CI = 95% confidence interval; R = Pearson's correlation; PRFD = peak rate of force development.

Table 3. Isometric mid-thigh pull force–time curve results.

		Treatment Conditions			1 × 3 ANOVA		
		T1	T2	T3			
Variables		Mean ± SD	Mean ± SD	Mean ± SD	P	η²	1 − β
Peak Force @ 50 ms	(N)	1351.8 ± 487.2	1337.7 ± 457.1	1394.5 ± 535.2	0.64	0.09	0.10
Peak Force @ 90 ms	(N)	1838.5 ± 754.6	1744.5 ± 666.8	1811.5 ± 732.0	0.74	0.07	0.09
Peak Force @ 200 ms	(N)	3013.3 ± 1000.0	2875.5 ± 874.90	3019.3 ± 988.1	0.59	0.11	0.12
Peak Force @ 250 ms	(N)	3096.3 ± 1064.0	2931.9 ± 951.6	3078.9 ± 1057.1	0.36	0.21	0.20
Maximal Peak Force	(N)	4466.8 ± 1580.7	4469.7 ± 1574.7	4325.6 ± 1543.2	0.32	0.22	0.21
PRFD @ 0–50 ms	(N·s⁻¹)	7744.3 ± 5521.7	7123.9 ± 6084.3	7845.7 ± 5979.5	0.86	0.03	0.07
PRFD @ 0–90 ms	(N·s⁻¹)	9998.7 ± 6263.6	8262.0 ± 5604.3	9370.7 ± 5659.6	0.36	0.20	0.19
PRFD @ 0–200 ms	(N·s⁻¹)	8775.7 ± 4419.3	8796.2 ± 4043.7	10,123.0 ± 4525.1	0.33	0.22	0.21
PRFD @ 0–250 ms	(N·s⁻¹)	8680.2 ± 3618.8	7740.4 ± 3025.7	8172.9 ± 3057.9	0.20	0.30	0.30

Note: T1 = isometric pull-sham treatment; T2 = isometric pull vibration treatment; T3 = isometric pull vibration treatment; PRFD = peak rate of force development; ANOVA = analysis of variance.

Table 4. Allometrically scaled isometric mid-thigh clean pull force–time curve results.

Variables		Treatment Conditions			1 × 3 ANOVA		
		T1	**T2**	**T3**			
		Mean ± SD	**Mean ± SD**	**Mean ± SD**	**P**	**η^2**	**1 − β**
Peak Force @ 50 ms	(N)	65.6 ± 14.0	65.5 ± 14.8	67.5 ± 16.2	0.73	0.07	0.09
Peak Force @ 90 ms	(N)	88.7 ± 24.5	85.3 ± 24.8	87.4 ± 22.7	0.78	0.05	0.08
Peak Force @ 200 ms	(N)	147.4 ± 33.0	141.7 ± 29.7	147.8 ± 32.4	0.67	0.08	0.10
Peak Force @ 250 ms	(N)	150.8 ± 31.9	144.0 ± 32.3	150.0 ± 31.7	0.44	0.17	0.16
Maximal Peak Force	(N)	218.2 ± 49.9	218.5 ± 51.7	211.4 ± 49.6	0.35	0.21	0.20

Note: T1 = isometric pull-sham treatment; T2 = isometric pull vibration treatment; T3 = isometric pull vibration treatment; PRFD = peak rate of force development.

There were only trivial to small correlations between body mass and the percent difference in potentiation for peak force at 50 ms (T1 vs T2: r = −0.29; T1 vs T3: r = 0.29), 90 ms (T1 vs T2: r = −0.46; T1 vs T3: r = 0.02), 200 ms (T1 vs T2: r = −0.39; T1 vs T3: r = −0.08), and 250 ms (T1 vs T2: r = −0.48; T1 vs T3: r = −0.11). Similar results were found when looking at the RFD results at 50 ms (T1 vs T2: r = −0.33; T1 vs T3: r = −0.23), 90 ms (T1 vs T2: r = −0.36; T1 vs T3: r = −0.40), 200 ms (T1 vs T2: r = −0.04; T1 vs T3: r = 0.14), and 250 ms (T1 vs T2: r = −0.36; T1 vs T3: r = −0.36).

3. Discussion

The primary finding of the present study was that the application of WBV at 30 Hz, 2−4 mm amplitude, 5 min prior to an isometric mid-thigh clean pull, resulted in no statistically significant improvements in any force/time variables. Similar to the present study, Cormie et al. [1] reported that the application of a 30 Hz, 2.5 mm amplitude WBV resulted in no statistically significant increases in peak force or RFD during the subsequent performance of an isometric back squat at 5, 10, or 30 min post WBV.

A careful examination of the individual subject's data revealed large individual variation regarding responsiveness to the WBV protocol. While the subjects had some resistance exercise background, a greater training age and strength level requirement, resulting in a more homogenous sample, may have lessened the degree of variation. It is possible that individual differences in muscle and tendon properties partially explain this phenomenon. Cardinale and Lim [19] suggest that the stiffness of an exposed muscle group is modulated by mechanoreceptors as well as dermal and epidermal receptors during WBV exposure. They hypothesized that there could be a large amount of individual variation in the body's damping effects to WBV, which may partially explain the inter-individual variation noted in the present investigation. It has been speculated that this dampening effect could also be related to the subject's overall body mass [3,30]. Interpretation of the correlation data from the present study appears to discount this contention, revealing non-significant, trivial correlations between body mass and percent change in select force–time characteristics. Recent studies have utilized electromyography to assess neural activation in response to various applications of WBV in an attempt to determine the most appropriate individualized WBV doses [19,23,30,34].

Another potential explanation for the present findings may center on individual subject differences in muscle fiber type, training state, reflex excitability, and overall level of fatigue [36]. Armstrong et al. [37] suggests that muscle fiber type may be a major factor dictating the responsiveness of a subject to a WBV protocol. In their study, the H-reflex was determined to express high levels of inter-subject variability, which was partially explained by the fiber type of the subject. However, the gender or training status of the subjects did not appear to be responsible for the differences noted in the H-reflex. Additionally, Adams et al. [2] noted that increased motor unit rate coding, synchronization, muscular coordination, and proprioceptor responses were related to acute improvements in strength and power performance seen following WBV exposure. The variability and lack of statistically significant findings in the present investigation may be partially explained by individual differences in

fiber type and neuromuscular responsiveness to the WBV protocol. For example, owing to individual responses, perhaps 5 min was too long and the acute performance benefit was missed.

While every attempt was made to minimize the pre-testing level of fatigue, it is possible that this affected the outcome measures collected during the isometric mid-thigh pull. Additionally, the training status of the subjects used in the present study may have impacted the effectiveness of the WBV protocol as a pre-conditioning activity [38]. Contrary to Armstrong et al. [37], Cochrane et al. [38] suggested that training status can significantly impact a subject's responsiveness to a WBV stimulus. The same authors reported no ergogenic effect following an acute WBV protocol in non-elite athletes, suggesting elite athletes may have responded more favorably. Specifically, they suggest that elite athletes have more fine-tuned central nervous system control, which may facilitate muscle and mechano-receptor sensitivity. On the basis of these findings, it is plausible that heavily resistance trained athletes may exhibit greater responsiveness to the WBV protocol used in the present study.

While there were no statistically significant increases in the variables measured in the present study, it is possible there is still a positive effect in response to the WBV protocol. Hopkins et al. [35] suggest that an absolute increase of 10% should be considered as the minimum worthwhile increase in a treatment-induced alteration. Additionally, a coefficient of variance of 0.3–0.6% appears to be an important change for elite athletes. For example, increasing the coefficient of variance by 0.6% increases the chance of winning a competitive event by $\approx$9–19% [35]. Therefore, on the basis of the changes in the coefficient of variance noted in this study, it is possible that the application of a WBV protocol may have a meaningful result when applied to an athletic population. In the present study, the application of a WBV protocol resulted in increases in the coefficients of variance when compared with the sham protocol of the magnitude of 3.9–60.6%, depending upon the variable analyzed. With such high coefficients of variance, there is the potential for some acute ergogenic benefit of the WBV protocol, but more research, especially with high level athletes, and possibly with larger sample sizes, is warranted to further investigate this hypothesis.

Additional support for this hypothesis can be found by examining the 95% percent confidence intervals noted for each of the coefficients of variance calculated and presented in Table 5 [28]. Batterham and Hopkins [28] suggest that a three-level scale of magnitude can be used to determine meaningfulness in a data set: beneficial, trivial, and harmful effects. In the present study, it may be inferred based upon the 95% confidence intervals that the effect of WBV on the peak force generated at 50, 90, 200, and 250 ms yielded trivial effects (Table 5). Conversely, using the same technique, a beneficial effect was noted for WBV effect upon peak RFD from 0 to 50 ms, 0 to 90 ms, and 0 to 200 ms (Table 5). Additionally, as the *p*-values determined for the peak RFD at 0–90 ms ($p = 0.36$), 0–200 ms ($p = 0.33$), and 0–250 ms ($p = 0.30$) were all between 0.05 and 0.50, it is difficult to determine the effects of WBV, as *p*-values in these ranges are suggested to be in an indeterminate range [39]. Thus, it might be suggested that chronic use of WBV may result in an enhancement in select force–time characteristics. This contention may be supported by the statistically significant increases seen in vertical jump performance reported to occur as a result of 3–4 months of WBV [8–11].

Table 5. Coefficient of variance, intraclass correlations, and interclass correlations between treatment conditions.

Variable	T1 vs T2						T1 vs T3					
	CV %	95% CI	ICCα	95% CI	R	95% CI	CV%	95% CI	ICCα	95% CI	R	95% CI
Peak Force @ 50 ms	11.7	8.0–21.4	0.93	0.75–0.98	0.92	0.71–0.98	7.4	5.1–13.3	0.97	0.90–0.99	0.97	0.89–0.99
Peak Force @ 90 ms	14.5	9.9–26.8	0.92	0.73–0.98	0.91	0.68–0.98	8.0	5.5–14.5	0.98	0.91–0.99	0.97	0.89–0.99
Peak Force @ 200 ms	10.8	7.5–19.8	0.93	0.77–0.98	0.93	0.75–0.98	3.9	2.7–7.0	0.99	0.97–1.00	0.99	0.96–1.00
Peak Force @ 250 ms	8.9	6.1–16.1	0.96	0.85–0.99	0.95	0.82–0.99	3.8	2.6–6.8	0.99	0.97–1.00	0.99	0.96–1.00
Maximal Peak Force	4.2	2.9–7.5	0.99	0.96–1.00	0.99	0.96–1.00	5.9	4.1–10.7	0.98	0.93–0.99	0.98	0.91–0.99
PRFD @ 0–50 ms	60.6	41.9–112.6	0.76	0.43–0.91	0.74	0.35–0.91	40.1	28.3–71.1	0.88	0.69–0.96	0.87	0.64–0.96
PRFD @ 0–90 ms	33.5	23.8–58.5	0.89	0.70–0.96	0.88	0.65–0.96	23.5	16.9–39.9	0.93	0.82–0.98	0.94	0.81–0.98
PRFD @ 0–200 ms	34.6	23.1–68.5	0.72	0.25–0.92	0.70	0.17–0.92	30.8	20.6–60.2	0.78	0.37–0.94	0.76	0.30–0.93
PRFD @ 0–250 ms	15.3	11.1–25.4	0.92	0.78–0.97	0.91	0.75–0.97	7.9	5.8–12.8	0.98	0.93–0.99	0.98	0.94–0.99

Note: CV = coefficient of variance; 95% CI = 95% confidence interval; T1 = mid-thigh pull sham treatment; T2 = mid-thigh pull vibration treatment 1; T2 = mid-thigh pull vibration treatment 2; PRFD = peak rate of force development.

On the basis of the current research, the application of a 30 Hz, 2–4 mm amplitude vibration does not result in any statistically significant alterations in isometric mid-thigh pull force/time characteristics in recreationally trained males. However, it is still possible that the changes in performance noted by the coefficient of variance and the 95% confidence intervals suggest a performance enhancing effect following WBV application. This finding is somewhat in line with research suggesting that the application of WBV can be used as a warm-up protocol for jumping activities [1]. The use of a higher frequency and amplitude combination may produce different results. However, any positive benefits seen following acute WBV application are likely related to the training status of the individual as well as the activity used after the warm-up protocol. More research is needed in order to determine the optimal application of WBV in field-based settings using both athletes and non-athletes.

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