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**Research article**

# Does Acute Vibration Exercise Enhance Horizontal Jump Performance?

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**Abstract**
The aim of this study was to investigate the acute effect of vibration exercise (VbX) on repetitive horizontal jumping performance and to examine the duration of the rest interval between the horizontal jump sets following acute VbX. Fourteen track athlete males (age 20.8 ± 1.8 yr; height 1.80 ± 0.05 m; body mass 73.1 ± 7.5 kg) performed four conditions in a randomised order; (a) VbX with 1 min rest between repetitive horizontal jump (RHJ) sets [VbX-1min]; (b) VbX with 2 min rest between RHJ sets [VbX-2min]; (c) No VbX with 1 min rest between RHJ sets [Con-1min]; (d) No VbX with 2 min rest between RHJ sets [Con-2min]. Intermittent VbX (six 60 s exposures with 30 s rest) at 26 Hz (6 mm peak-to-peak displacement) was performed in an isometric squat position (120° of knee flexion). The mean values of distance, velocity and time taken of RHJ from the four conditions were used in repeated measures [condition (VbX and Control) and rest period (1min; and 2min)] ANOVA. There was a condition effect such that VbX significantly increased RHJ distance ($p < 0.05$) compared to control (no VbX). Furthermore, VbX significantly increased RHJ velocity ($p < 0.05$) compared to no VbX and there was an interaction effect (condition x rest) where the velocity was significantly higher in VbX-2min compared to VbX-1 min, Con-2min, and Con-1min respectively. Acute intermittent VbX has the ability to enhance repetitive horizontal jump distance and velocity, which could be used as an additional method for warm-up intervention to increase explosive power performance.

**Key words:** Repetitive jump, sets, rest, recovery, velocity.

## Introduction

Explosive power is a quality that most athletes require for sporting prowess and conventional methods such as resistance and plyometric training have been the mainstay for enhancing power (Cronin and Sleivert, 2005; De Villarreal et al., 2011). Recently, however whole-body vibration or vibration exercise (VbX) has gained popularity as a form of neuromuscular training due to its time efficiency and ease of use. The most common form of VbX is achieved by standing on a commercially manufactured machine with an oscillating platform, which moves in the vertical plane or moves in a side-alternating motion about a central axis. The platform produces periodic vertical sinusoidal oscillations, where energy is transferred to the human body. Through the rapid eccentric-concentric muscle action caused by the vertical sinusoidal oscillations, this transient effect to enhance muscle performance is thought to be mediated by a rapid reflex and stretch-reflexes (Ritzmann et al., 2010), which is likely to involve the tonic vibration reflex (Pollock et al., 2012). However, other mechanisms of muscle temperature, blood flow and post-activation potentiation are enhanced following VbX (Cochrane et al., 2010; 2008; Kerschan-Schindl et al., 2001; Rønnestad and Ellefsen, 2011) and may contribute to increasing muscle performance (Cochrane, 2013).

Most sporting movements produce eccentric and concentric muscle actions with a combination of horizontal, vertical and/or anterior-posterior ground reaction forces where lower-limb power measures are often assessed by various vertical and horizontal jump tests (Maulder and Cronin, 2005). To date, a number of studies have reported that countermovement jump (CMJ) is enhanced following acute VbX in elite field-hockey players (Cochrane and Stannard, 2005), trained recreational athletes (Bedient et al. 2009, Cormie et al. 2006, Bosco et al. 2000) although one study has reported no effect in elite athletes (Bullock et al., 2008). Furthermore, Bosco et al. (1999) observed that following acute VbX, single-leg press power increased (6-8%) across loads of 70, 90, 100, 139 kg in elite volleyball players and in male college athletes squat power increased 5.2 % after receiving acute VbX (Rhea and Kenn, 2009). Given the potential of VbX as alternative exercise modality to increase explosive muscle performance the majority of the aforementioned studies have only focused on single acyclic movement performed in the vertical plane but there is paucity of research on the acute effect of VbX on horizontal jump performance. It has been suggested that further research is required with trained athletes to ascertain if acute VbX can potentiate stretch-shortening cycle activities, such as, repetitive horizontal jumping (Wilcock et al., 2009). It is well established that repetitive jump tests in the horizontal plane can provide a reliable and valid measure to assessing lower-leg power (Maulder and Cronin 2005) and that cyclic horizontal jump tests are capable of replicating power and force characteristics that occur in various athletic movements (Moresi et al., 2011). Therefore, this study proposes to address whether acute VbX can enhance explosive muscle actions in the horizontal plane by assessing bilateral horizontal repetitive jump performance.

Following VbX any changes associated with muscle performance will be dependent on the manipulation of VbX parameters, such as; vibration frequency (Hz), vibration peak-to-peak displacement (mm) and vibration duration (min or s). Although, there are a multitude of VbX combinations, a number of studies have examined optimal acute VbX guidelines for muscle performance (Adams et al., 2009, Da Silva-Grigoletto et al., 2011; Gerodimos et al., 2010; Ritzmann et al., 2013). However, there is a paucity of research on the duration of the rest interval between successive bouts or sets of muscle performance

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following acute VbX. Adams et al. (2009) reported that countermovement jump peak power was enhanced 1-5 mins following acute VbX and Cochrane et al., (2010) found that post-90s of VbX, the rate of force development was significantly higher compared to control and no vibration interventions. In the resistance training literature it has been documented the rest interval between sets of exercises is an important acute parameter when designing a resistance programme (Evangelista et al., 2011; De Souza et al. 2010), which can influence muscular performance (Pincivero et al. 1997; Robinson et al. 1995). Further, eliciting post-activation potentiation relies on many factors that include optimising the rest interval between the conditioning activity and outcome measure but often it has produced conflicting results (Comyns et al., 2006; Wilson et al., 2013). Similarly, little is known about the rest period when undertaking sets of explosive power movement and previous research has suggested that a closer examination of whether 1 or 2 min is sufficient to maintaining power aspects between repeated sets (Willardson, 2006).

Previous acute VbX research has focused on acyclic vertical jump performance, which has been shown to significantly increase CMJ height (Bazett-Jones et al., 2008; Bosco et al., 2000; Cochrane and Stannard, 2005; Cormie et al., 2006; Torvinen et al., 2002). However, no study has assessed the effect of acute VbX on cyclic horizontal jump performance. Therefore, the aim of this study was to investigate the acute effect of VbX on repetitive (cyclic) horizontal jumping performance and to examine the duration of the rest interval between the horizontal jump sets following acute VbX. Based from previous research that acute VbX can enhance acylic bilateral CMJ height (Bazett-Jones et al., 2008; Bosco et al. 2000; Cochrane and Stannard 2005; Cormie et al., 2006; Torvinen et al. 2002), it was hypothesised that repetitive horizontal jump performance would increase from an acute bout of VbX. As a secondary hypothesis, it was postulated that following VbX, that a larger rest period (2min) between horizontal jump sets would increase performance.

## Methods

### Participants

Fourteen track athlete males (age 20.8 ± 1.8 yr; height 1.80 ±0.05 m; body mass 73.1 ± 7.5 kg) volunteered for the study of which six participants were competing at the national level and eight participants at club level in events of jumping (high, long, or triple jump) or sprinting (100m, 200m, or 400m). The study was conducted over a three week period at the beginning of the athletes' off-season where they were undertaking at least two training sessions per week as part of their off-season programme. Written informed consent was obtained from participants, and ethical approval was granted by the University Human Ethics Committee.

### Study design

Every participant performed four conditions; (1) VbX with 1 min rest between repetitive horizontal jump (RHJ) sets [VbX-1min]; (2) VbX with 2 min rest between RHJ sets [VbX-2min]; (3) No VbX with 1 min rest between RHJ sets [Con-1min]; (4) No VbX with 2 min rest between RHJ sets [Con-2min]. All conditions were randomised and conducted at least 24 hr a part. A 90 s rest was enforced from the completion of the VbX and control before the commencement of the first RHJ set (Figure 1).

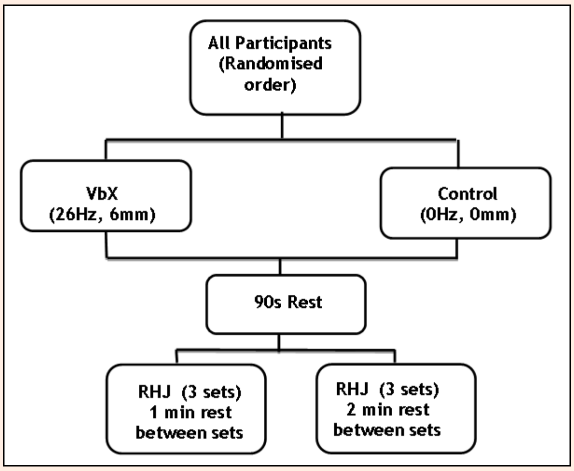


**Figure 1.** Study design.

All jumps were conducted in a laboratory with a on a vinyl floor and testing was performed at the same time of day in order to account for daily biorhythms. Participants were also instructed to refrain from physical and power training at least 24 hr before each testing session. A separate familiarisation session was held for participants three days prior to testing where participants practiced the repetitive horizontal jump to determine its execution, which was observed by the main researcher who provided feedback on correct jump technique, and all participants were familiarised with VbX protocol. To reduce the possibility of influencing the outcome of the study a warm-up was prohibited prior to each condition.

### Vibration exercise (VbX)

VbX was performed on a commercial machine (Galileo Sport, Novotec, Pforzheim, Germany), which had a motorised teeterboard that rotated around an anteroposterior horizontal axis to produce side-alternating vertical sinusoidal vibrations to the body. The VbX machine was set to 26 Hz and participants were instructed to place each foot 18 cm from the central axis, which corresponded to a peak-to-peak displacement of 6.4 mm. A single axis accelerometer (Imems®, ADXL250, Analog Devices, Norwood, MA, USA) was secured to the edge of the vibrating platform and recorded an acceleration of 9.2 ± 0.02 *g*. Participants stood in an isometric squat position (120° of knee flexion), for six 60 s exposures with 30 s rest (standing to the side of the machine). The vibration frequency of 26 Hz was selected based on previous VbX research that reported an increase in neuromuscular excitability (Rittweger et al., 2003), blood flow (Kerschan-Schindl et al., 2001) and muscle temperature (Cochrane et al. 2008). The static squat was measured at the beginning of each exposure with a manual goniometer. Every participant was instructed to placed their hands on their hips, maintain an upright torso and evenly distribute their weight through the soles of their feet for vibration and control trials. For the control condition the vibration machine was switched off and participants performed the exact stance (static squat, hands on hips, upright torso) and duration.

### Repetitive Horizontal Jump (RHJ)

Participants started the test with both feet parallel on a marked start line; with use of their arms participants were instructed to take three maximal jumps on two feet to cover the greatest horizontal distance as possible with minimal ground contact time. Using a floor mounted tape measure, the distance covered by the three consecutive jumps was determined from the start line to the heel closest to the start line. Three sets of three consecutive RHJ were performed with either 1 min or 2 min rest separating each set.

A video camera (Casio Ex-F1, Tokyo, Japan) with a sampling rate of 100 Hz captured each RHJ. The camera was positioned at the 4 m mark and placed 3m lateral to the participant's jumping plane where the camera height was set at 0.7 m. Video recordings of RHJ were analysed by MaxTraq (Standard 2.08, Innovision Systems Inc, Columbiaville, MI, USA) to determine the time taken to complete RHJ. The time taken was the period between toe-off and heel strike. Velocity was calculated from the equation $v = st^{-1}$, where $v$ is the velocity; $s$ is the displacement; and $t$ is the time taken for RHJ.

### Statistical analyses

The mean RHJ values from the three sets of distance, velocity and time were used in repeated measures [condition (VbX and Control) and rest period (1min; and 2min)] ANOVA and were performed in conjunction with Bonferroni adjustment. Effects sizes were measured by partial Eta square ($\eta_p^2$) an effect size of 0.1-0.3 was classified as small; 0.3-0.5 as moderate; 0.5-0.7 as large; and 0.7-0.9 very large (Hopkins, 2002). It has previously been reported that the reliability of RHJ of intraclass correlation coefficient and coefficient of variation was 0.95 and 1.9% (Maulder and Cronin, 2005). The level of statistical significance was set at $p < 0.05$, and all statistical analyses were computed using SPSS for Windows (version 20.0, IBM, New York, USA).

## Results

There was a condition effect such that VbX significantly increased RHJ distance ($p < 0.05$, $\eta_p^2$=0.289) compared to control (no VbX) (Table 1). However, there was no significant rest effect for RHJ distance when 1 min or 2 min rest was enforced between RHJ sets for VbX and control conditions. VbX significantly increased RHJ velocity ($p<$ 0.05, $\eta_p^2$ = 0.402) compared to no VbX (Figure 2) and there was an interaction effect (condition x rest) where the velocity was significantly higher in VbX-2min ($p < 0.05$, $\eta_p^2$ = 0.319) compared to VbX-1 min, Con-2min, and Con-1min respectively (Table 1). There was no significant difference in the time taken to complete the horizontal jumps for the conditions and rest periods (Table 1).

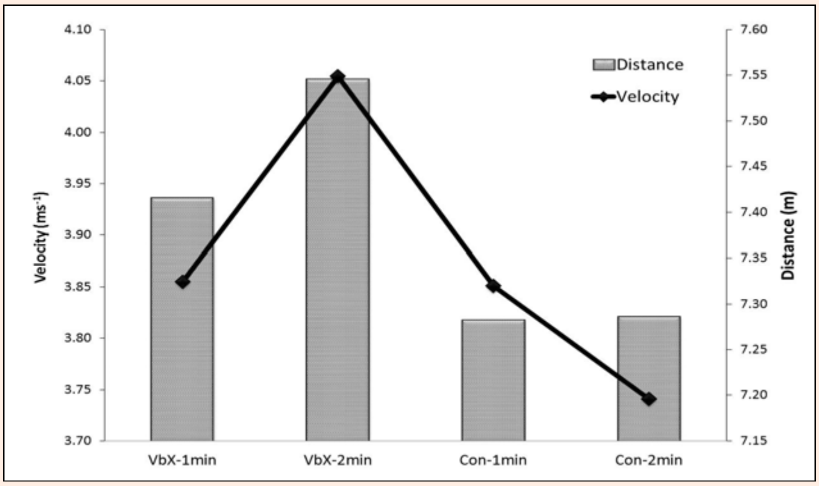


**Figure 2. RHJ distance and velocity following VbX and Control for 1 min and 2 min rest separating RHJ sets. The statistical differences are noted in Table 1.**
VbX-1min - VbX with 1 min rest between RHJ sets. VbX-2min - VbX with 2 min rest between RHJ sets
Con-1min - No VbX with 1 min rest between RHJ sets. Con-2min - No VbX with 2 min rest between RHJ sets.

**Table 1. Mean (±SD) of RHJ distance, velocity and time taken following VbX and Control for 1 min and 2 min rest separating RHJ sets.**

| Condition<br>Rest | VbX-<br>1min | VbX-<br>2min | Con-<br>1min | Con-<br>2min | Statistical Analysis<br>Condition effect | <br>Rest effect | <br>Condition x Rest effect |
|---|---|---|---|---|---|---|---|
| Distance (m) | 7.42 (.94) | 7.55 (.90) | 7.28 (.99) | 7.29 (.87) | p < .05‡ | p = .341 | p = .228 |
| Velocity ($m·s^{-1}$) | 3.85 (.48)* | 4.05 (.54) | 3.85 (.45) * | 3.74 (.45) ** | p < .05 ‡ | p = .229 | p < .05 † |
| Time (s) | 1.98 (.21) | 1.89 (.30) | 1.90 (.24) | 1.96 (.19) | p =.493 | p =.961 | p =.057 |

* p < 0.05, **p < 0.01 significantly different from VbX-2min. † significant (p < 0.05) condition (VbX) x rest interaction. ‡ significant (p < 0.05) condition effect (VbX)

## Discussion

The primary finding of this study was that acute intermittent VbX (26 Hz, 6 mm peak-to-peak displacement) significantly enhanced RHJ distance compared to no VbX. The present finding of ~3% improvement in RJH distance is similar to vertical acylic CMJ improvement following acute VbX (Bosco et al., 2000; Cormie et al., 2006; Torvinen et al., 2002) however, using a 5 s continuous vertical jump protocol Bosco and co-workers (1998) reported a larger jump height increase (12%) following acute VbX. This can be explained by the differences in jumping technique. For instance, in the vertical jump, the distance is a sum of the rise of the centre of mass due to plantarflexion and actual jump height. In contrast, for the horizontal jump it is the sum of the take-off, flight and landing distances. Therefore, the percentage contribution of the flight distance in the horizontal jump is smaller than the vertical jump, which has less effect on horizontal than vertical jump performance. In the present study, RHJ velocity was significantly enhanced by ~4% following acute VbX, which is in agreement with Bosco et al., (1999) where velocity of a single-leg press increased 6%-8% at various loads (70-130kg) after an acute bout of VbX. However, caution is required when making comparisons between the current findings and those studies that have used acyclic or cyclic vertical jump tests due to the differences in jump kinetics and kinematics.

The aforementioned studies indicate that muscle function is enhanced from acute VbX and although electromyography was not collected in the present study but there is a claim that neural factors may be responsible for the acute increase in muscle performance, which are similar to the chronic neural changes seen in traditional resistance and power training (Bosco et al., 1999). However, the mechanism(s) of acute VbX have yet to be fully elucidated; currently there are several different theories to explaining the transient effect of acute VbX. It has been previously discussed that aspects of the neuromuscular system such as motor unit recruitment, synchronisation, and co-contraction may be responsible for force and power increases following acute vibration (Cochrane, 2011; Pollock et al., 2012). Further, there is evidence to suggest that acute VbX is likely to involve the tonic vibration reflex (Pollock et al. 2012), which is facilitated by reflex-mediated stretch-shortening (Ritzmann et al. 2010); additionally, a temporal relationship exists between muscle activity and muscle contractile displacement, indicating that muscle lengthening may be a precondition to eliciting probable stretch reflexes (Cochrane et al., 2009).

Further, the warm-up effect of acute VbX may contribute as an additional mechanism to enhancing muscle performance (Cochrane, 2013). The temperature related warm-up effect of muscle temperature has been shown to significantly increase its rate from an acute bout of VbX compared to traditional active and passive warm-up methods (Cochrane et al., 2008). Likewise, non-temperature related warm-up aspects may play a role in increasing muscle performance. For example, acute VbX has been shown to increase blood flow of the popliteal artery (Kerschan-Schindl et al., 2001) and depending on the extent of prior work done, the muscles' performance can be enhanced, most likely through post-activation potentiation. Depending on the vibration parameters, acute VbX has the ability to act as a conditioning activity by enhancing muscle twitch peak force, rate of force development (Cochrane et al., 2010) and 40m sprint performance (Rønnestad and Ellefsen, 2011), suggesting that myogenic aspects may be responsible to eliciting post-activation potentiation. But acute VbX faces similar challenges of other conventional exercises to induce post-activation potentiation that requires additional research on the optimisation of certain parameters such as; volume, intensity, recovery interval, type of activity and training characteristics. However, it is difficult to postulate which mechanism(s) are responsible for the increase in RHJ distance and velocity as it was beyond the scope of the present study to examine muscle and reflex activity, muscle temperature, and blood flow. Nonetheless, the enhancement in RHJ distance and velocity following acute VbX reflects neuromuscular changes and/or an ergogenic effect.

Having sufficient rest between performance sets has received little attention but it remains an important aspect when assessing or prescribing exercise programmes. Normally a rest period of three minutes between sets has been suggested for explosive-related exercises (Willardson, 2006), which allows for the regeneration of energy stores and force generation (Harris et al. 1976, Goto et al. 2004). However, we examined whether 1 or 2 mins rest was sufficient to maintaining lower-body explosive power measures between repeated sets, which has been identified as an area requiring further investigation (Willardson, 2006). In the present study following VbX, there was no effect on jump distance when either 1 min or 2 min rest was enforced between RHJ sets. However, the velocity was enhanced after VbX, when a 2 min rest was enforced between the RHJ sets compared VbX and control respectively. Contrary, Marin et al. (2011) reported that when bench press sets were interspersed with vibration or passive rest, bench press velocity was significantly higher in set 1 compared to set 2 and 3. Our results indicate that following VbX, jumping velocity can be enhanced when 2 min rest is enforced between repeated attempts of explosive lower-limb movement. However, future research should examine whether 3 mins rest between repeated explosive-power exercises is capable of enhancing movement velocity following acute VbX.

## Conclusion

To the best of our knowledge, this current study is the first to report that intermittent VbX exposure increases repetitive horizontal jump distance and velocity. Further, acute VbX can enhance velocity of explosive movement when a 2 min rest is enforced compared to a 1 min rest between repeated bouts or sets of explosive exercises. However, it is still unclear what mechanism(s) are responsible for the increase in jump distance and velocity and future research should focus on the neural and ergogenic effects of acute VbX.

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## Key points

- Acute intermittent VbX can enhance repetitive horizontal jump distance and velocity.
- Acute intermittent VbX may be used as an additional method for warm-up intervention to increase explosive power performance.

## AUTHORS BIOGRAPHY

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