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SHORT REPORT

Differential effects of whole body vibration durations on knee extensor strength

James A. Stewart^a, Darryl J. Cochrane^b, R. Hugh Morton^{c,*}^a *New Zealand Institute of Sport, Wellington, New Zealand*^b *Sport Management and Coaching, Massey University, Palmerston North, New Zealand*^c *Institute of Food, Nutrition and Human Health, Massey University, Palmerston North, New Zealand*

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Summary The effectiveness and optimality of whole body vibration (WBV) duration on muscular strength is yet to be determined. Hence the aim of this study was to investigate the effects of three different durations of continuous WBV exposure on isometric right knee extensor strength measured pre and post exposure. The study involved 12 trained male subjects (age 23.7 ± 4.2 years, height 1.82 ± 0.06 m, weight 81.8 ± 15.5 kg). Pre and post knee extensor strength was measured using the BiodexTM System 3. Peak and mean torques were recorded over three maximal 2 s contractions with 10 s intervals. All subjects completed three interventions of WBV lasting 2, 4, or 6 min, in a balanced randomized order. Whole body vibration was performed on the GalileoTM machine set at 26 Hz with peak-to-peak amplitude of 4 mm. We found significant interaction (duration \times pre–post) effects for both peak and mean torque. Two minutes of WBV provided a significantly different ($p < 0.05$) effect (peak torque +3.8%, mean torque +3.6%) compared to 4 min (–2.7% and –0.8%, respectively), and compared to 6 min (–6.0% and –5.2%, respectively), while 4 min produced significantly different results compared to 6 min for peak torque measurements only. Two minutes of WBV produced an improvement in isometric right knee extension strength compared to 4 and 6 min, both of which produced strength decreases. Nevertheless, the mechanisms and optimal dose–response character of vibration exposure remain unclear.

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Introduction

Whole body vibration (WBV) has become increasingly popular with many coaches, trainers, and

athletes for conditioning, rehabilitation, and general fitness. Whole body vibration has been reported to give both performance and health benefits, including increases in muscle power,¹ and a reduction in the occurrence of falls in the elderly.² The likely explanation for such effects is that the vibration causes a neurogenic and muscle response known as tonic vibration reflex, which activates the

* Corresponding author.

E-mail address: H.Morton@massey.ac.nz (R.H. Morton).

muscle spindles thereby enhancing the excitatory drive reflex of the alpha motoneurons.³ However other investigators have reported no change in muscular performance,^{4,5} and it is known that lengthy vibration exposure is a precursor to inhibiting motor unit recruitment.⁶ These discrepancies may be attributable to different devices, body positions, frequencies, amplitudes, and durations.

Currently, there are no prescriptive guidelines for vibration exercise and a lack of consensus on an appropriate, safe, and effective duration exposure. For example de Ruiter et al.⁵ used a 5 min \times 1 min exposure with 2 min rest (frequency 30 Hz, amplitude 8 mm); Cochrane and Stannard¹ employed a 4 min \times 1 min and 2 s \times 30 s protocol with no rest (frequency 26 Hz, amplitude 6 mm); and Torvinen et al.⁴ used 4 min continuous exposure (frequency 15–30 Hz, amplitude 8 mm).

Clearly, the effectiveness and optimality of WBV duration on muscular strength is yet to be determined. Therefore the aim of this study was to investigate the effect of 2, 4, and 6 min of continuous WBV exposure on isometric knee extensor strength.

Materials and methods

Twelve trained male subjects, (age 23.7 ± 4.2 years, 1.82 ± 0.1 m, 81.8 ± 15.5 kg) having no prior experience of WBV gave their informed consent and volunteered to participate in the study, as approved by the University Human Ethics Committee.

All subjects attended a familiarisation session prior to the main study, gaining experience of both WBV and knee extension strength measuring equipment. WBV utilised the GalileoTM SPORT Professional (Novotec, Pforzheim, Germany) vibration platform. Right knee maximal voluntary isometric contractions were performed on the BiodexTM System 3 (Biodex Medical Systems, Inc., New York, USA) muscle dynamometer. Testing sessions were conducted in a thermally neutral environment (temperature 21 °C, relative humidity 40%) at the same time of day. Subjects did not engage in any strenuous activity within 24 h of testing.

In the main study each subject experienced three WBV exposure durations (2, 4, and 6 min) in balanced and randomized order allowing at least 24 h recovery between each session. These durations were selected based on the Torvinen et al. study⁷ in which 4 min of continuous WBV increased leg extension strength. Subjects stood in shoes on the platform, knees flexed at approximately 5°, with feet positioned equidistant from the central

oscillating axis, and with weight evenly distributed between the legs. Vibration frequency was set at 26 Hz with peak-to-peak amplitude 4 mm, similar to a previous study.¹

Strength testing entailed three maximal 2 s contractions separated by 10 s rest. Pre and post testing were completed within 90 s either side of vibration exposure. Peak torque was recorded as the maximum, while mean torque was calculated from all three contractions. The range of movement was set at 110° knee flexion and 5° extension. Isometric contractions were performed in extension at 75° from horizontal. No warm-up was allowed prior to testing.

Peak and mean torques were analysed by repeat measures analyses of variance using standard software (Minitab Inc., State College, PA). Duration effects were assessed within subjects, and pre–post differences and their interaction with duration were assessed within durations. Scheffe's post-hoc test was applied to ascertain specific differences. The level of statistical significance was set at $p \leq 0.05$.

Results

Mean baseline (pre) peak and mean torque values were not significantly different. Both post sets of torque values showed similar patterns of linear decline with exposure duration ($p \leq 0.05$). The mean (S.D.) pre–post knee extensor strength differences (% changes) after 2 min of WBV exposure were +3.8% (1.7) peak torque, +3.6% (1.2) mean torque; 4 min –2.7% (1.4) peak torque, –0.8% (1.0) mean torque; 6 min –6.0% (2.2) peak torque, –5.19% (1.7) mean torque.

Detailed ANOVA revealed significant interactions between pre–post differences and exposure dura-

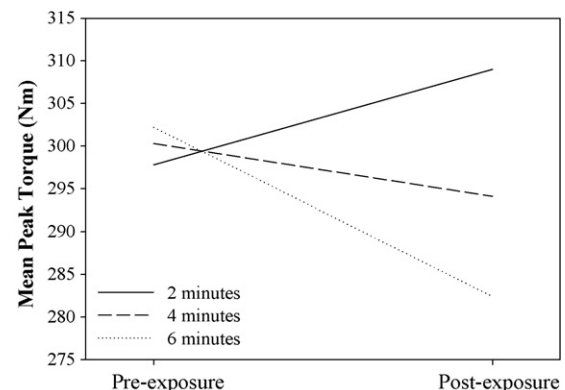


Figure 1 Pre and post mean peak torque values vs. exposure duration ($n = 12$).

tion ($p \leq 0.05$) for both peak and mean torques. The nature of this interaction is shown in Fig. 1.

Discussion

The duration of acute WBV is considered an important variable in understanding muscular performance, however the optimal duration for its use in sport performance, rehabilitation and uncompromised health remains equivocal. Therefore, the aim of the study was to investigate the effect of 2, 4, and 6 min of continuous WBV exposure on isometric knee extensor strength. The results of this study, showing that 2 min of continuous WBV produced an increase of 3.8% in peak torque, is partially in agreement with the Torvinen et al. study⁷ showing a 3.2% enhancement in isometric leg extensor strength. However that occurred after 4 min of exposure. The difference may be attributable to the different body positions, vibration frequencies, and amplitudes used. For example, Torvinen et al.,⁷ employed a series of dynamic movements involving jumping, squatting, and standing that corresponded to an increase in vibration frequency of from 15 to 30 Hz, which contrasts the static body position and vibration frequency of 26 Hz adopted in the present study. The peak amplitude of the present study was 4 mm which is in contrast to 8 mm used by other studies.^{5,7} We elected to use 4 mm on the basis that people new to WBV should not be exposed to lengthy periods of high peak amplitudes (8 mm) and accelerations (22 g).

In contrast to the present results de Ruiter et al.⁵, reported a 7% decrease in isometric knee extensor strength after 5 min \times 1 min 30 Hz WBV exposure. One cannot discount the possibility of fatigue occurring, however there were differences in WBV stance, with de Ruiter et al.⁵ employing a knee angle of 110°, compared to the 5° knee angle used in the present study. Moreover, the angle used to measure isometric strength of the current study was set at 75° knee extension, in contrast to 90° knee extension reported by other investigators.^{5,7}

Since no electromyography recordings were taken it is difficult to offer an explanation for the significant increase in strength after 2 min of WBV. One could speculate that WBV caused the muscle to briefly stretch, activating the 1a sensory endings of the muscle spindle thereby stimulating the alpha motoneurons to recruit inactive muscle fibres.⁸ Additionally, the vibration may have activated other sensory

receptors to heighten the gamma motoneuron system,⁵ thereby stimulating the primary afferent and promoting the sensitivity of the stretch reflex.

The present study found that WBV exposure for 4 and 6 min decreased peak torque by -2.7% and -6.0%, respectively. It has been previously reported that prolonged exposure has detrimental effects on performance.^{6,9} Indeed, Rittweger et al.⁹ has shown that by squatting up and down on a vibration plate in a 6 s cycle with an additional body load of 35–40% body mass significantly reduced vertical jump height and isometric knee extension strength.

Conclusions

In conclusion, 2 min of WBV produced a significant ($p < 0.05$) increase (+3.8%) in peak torque compared to 4 and 6 min. Conversely, peak torque decreased significantly ($p < 0.05$) after 4 and 6 min (-2.7%, -6%, respectively). Mean torques showed a very similar response. However, the optimal dose of vibration exposure remains unclear and further investigation should focus on intermittent and continuous protocols to provide relevant information on prescribing safe and effective WBV exposures for sport performance, rehabilitation, and the elderly.

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References

1. Cochrane DJ, Stannard SR. Acute whole body vibration training increases vertical jump and flexibility performance in elite female field hockey players. *Br J Sports Med* 2005;39:860–5.
2. Runge M, Rehfeld G, Rsnicek G. Balance training and exercise in geriatric patients. *J Musculoskel Neuron Interact* 2000;1:61–5.
3. Cardinale M, Bosco C. The use of vibration as an exercise intervention. *Exerc Sport Sci Rev* 2003;31:3–7.
4. Torvinen S, Sievanen H, Jarvinen TAH, et al. Effect of 4 min vertical whole body vibration on muscle performance and body balance: a randomized cross-over study. *Int J Sports Med* 2002;23:374–9.
5. de Ruiter CJ, van der Linden RM, van der Zijden MJA, et al. Short-term effects of whole-body vibration on maximal voluntary isometric knee extensor force and rate of force rise. *Eur J Appl Physiol* 2003;88:472–5.

6. Bongiovanni LG, Hagbarth KF, Stjernberg L. Prolonged muscle vibration reducing motor output in maximal voluntary contractions in man. *J Physiol* 1990;**423**:15–26.
7. Torvinen S, Kannus P, Sievanen H, et al. Effect of a vibration exposure on muscular performance and body balance. Randomized cross-over study. *Clin Physiol Funct Imaging* 2002;**22**:145–52.
8. Romaiguere P, Vedel JP, Pagni S. Effects of tonic vibration reflex on motor unit recruitment in human wrist extensor muscles. *Brain Res* 1993;**602**:32–40.
9. Rittweger J, Beller G, Felsenberg D. Acute physiological effects of exhaustive whole-body vibration exercise in man. *Clin Physiol* 2000;**20**:134–42.

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