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Comparing the Effectiveness of Whole Body Vibration and Local Vibration Exercise on Counter-Movement Jump Performance and Its Residual Characteristics in Well-Trained Athletes

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Abstract

Aim: This study aimed to compare the effectiveness of whole body vibration (WBV) and local vibration (LV) exercise on counter-movement jump performance (CMJ) and its residual characteristics in well-trained athletes.

Material and Methods: Thirty-two male athletes (age: 22.3±3.2 years) visited the laboratory twice, 48 hours apart, and performed WBV and LV in two sessions of equal duration. Each test day had two parts (sham [0 Hz, 0 mm] and vibration treatment [50 Hz, 4 mm]), 20 min apart. LV or WBV were applied for 6×15 sec with 1 min passive rest between repetitions. During the LV, participants were asked to lie supine (2×15 sec) and then lie laterally (2×2×15 sec) such that the quadriceps muscles connected to the WBV device. WBV was applied in the squatting position at 135° knee angle. After each session, the participants were tested for CMJ for 8 min at the 1st, 2nd, 3rd, 4th, 6th, and 8th min.

Results: The results of two-factor repeated measures ANOVA test revealed that both WBV ($p = 0.27$; $n_p^2 = 0.04$) and LV ($p = 0.57$; $n_p^2 = 0.03$) and their sham conditions decreased CMJ height to a similar extent. Further, there was no statistically significant difference between WBV and LV at any measurement time point ($p>0.05$).

Conclusion: WBV and LV were not effective methods to enhance the CMJ performance of well-trained athletes. However, WBV platform can be safely used as LV exercise equipment since no adverse effect was observed.

Keywords

Combat athletes
Vertical sinusoidal vibration
Explosive strength
Lower body

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INTRODUCTION

Whole Body Vibration (WBV) is a common exercise modality, used in fitness and health centers to increase muscle strength (Delecluse et al., 2003; Petit et al., 2010; Bosco et al., 1998; Mahieu et al., 2006; Giorgos et al., 2007; Savelberg et al., 2007; Luo et al., 2005), power (Luo et al., 2005; Adams et al., 2009), and flexibility (Fagnani et al., 2006; Dallas et al., 2012; Behm et al., 2011; Siegmund et al., 2014; Samson et al., 2012; Dadebo et al., 2004) in healthy humans. Vibration devices generate mechanical oscillation, which may affect the muscle spindles and Ia afferents, causing changes in the length of extrafusal fibers of muscles. This response to vibration resulting in the activation of an afferent feedback mechanism is known as tonic vibration reflex (TVR) (Hagbarth et al., 1996; Cardinale et al., 2003).The stimulus generated by the mechanical vibration causes a high level of stress on the musculoskeletal system (Abercromby et al., 2007; Roelants et al., 2006; Marin et al., 2009), and the level of stress determines the training load, which consists of frequency, amplitude, acceleration, and duration of vibration on the musculoskeletal system (Cardinale et al., 2008; Rittweger, 2010).However, some anatomical structures such as soft tissues, bones, and body fluids absorb some vibration load during WBV, and therefore, affect the amount of vibration load transmitted to the muscles (Cochrane, 2011). The amount of vibration load depends on the distance between vibration source and target muscles (Cochrane, 2011)and therefore the distal muscles may not effectively

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benefit from the vibration load to enhance performance (Drummond et al., 2014). However, local vibration (LV) may be more useful than WBV for targeting the muscles, because the muscles are directly exposed to the vibration in LV and absorption of the vibration is minimized (Drummond et al., 2014; Peer et al., 2009; Kurt et al., 2015). However, it is debatable whether LV is more effective than WBV in increasing the performance or in the treatment of injury. Another controversial topic is whether WBV equipment can be safely used for LV effectively.

Kurt (2015) reported that LV is an effective exercise modality that acutely increases lower extremity flexibility compared to WBV and traditional stretching exercises. Since the subjects experienced no negative effects during LV, this treatment could be considered a safe and effective way of enhancing lower extremity flexibility. Similarly, Peer et al. (2009) reported that LV therapy can have significant acute benefits for improving flexibility and reducing perceived stiffness in healthy adults with ankle or hamstring injury. These positive effects of LV are explained by the fact that since LV is applied directly to the affected area, its impact is likely to be more concentrated than that of WBV. This may trigger a greater response in the affected muscle, including contractility of the agonist and relaxation of the antagonist, facilitating a greater range of movement than WBV (Peer et al., 2009).

There are many studies in the literature related to WBV, including squatting exercises, which have been used in general. Most of these studies used static or dynamic squat movements without external loads on the WBV plate in order to study the WBV effects on jumping performance (Abercromby et al., 2007; Cochrane et al., 2005; Turner et al., 2011; Cardinale et al., 2003; Dallas et al., 2015; Bagheri et al., 2012).In the squat movements on the WBV device, the vibratory stimulus is indirectly transferred to the body through the feet (Drummond et al., 2014; Peer et al., 2009; Rehn et al., 2007).However, the absorption of vibration energy by the soft tissues of the body during transmission to muscles while squatting on WBV device, leads to a reduced vibratory stimulus to the target muscles during jumping. It can be said that a body position in which the muscles that are active during jumping, are closer to WBV device instead of the squat position may provide more effective results while measuring the effects of WBV training on jumping performance (Cochrane et al., 2011; Drummond et al., 2014; Cochrane et al., 2005).LV may be a more useful vibration treatment for target muscles during jumping, because in LV they are exposed to a higher vibration load compared to WBV when squatting on the device (Peer et al., 2009). Therefore, this study aimed; a) to compare the effects of WBV and LV on CMJ performance levels in well-trained athletes b) whether a WBV platform like Power Plate can be used as LV equipment safely and effectively in the athletic population. We hypothesized that both LV and WBV would increase CMJ height in well-trained athletes and that the WBV platform may be used as LV equipment safely and effectively to enhance performance.

METHOD

Participants

All procedures were approved by the ethics committee of a local university (approval no: 2014/162), and the study was carried out in accordance with the principles of the Declaration of Helsinki. Informed consent was provided by all volunteers participating in this study.

Thirty-two well-trained male athletes competing in sports like wrestling, judo, taekwondo, muay thai, and soccer (mean age 22.3 ± 3.2 year; mass: 73.1 ± 6.8 kg, training duration: 9.50 ± 4.27 hours/a week) were recruited for this study. The inclusion criteria for participants of the study were (i) performing physical activity for at least three or four hours per week, at least for the last three months, (ii) no injury or medical surgery related to lower extremities that could influence the test results, (iii) no functional limitation that could interfere with the test performance. The subjects had no health problems like diabetes, epilepsy, prostheses, neurological, or neuromuscular diseases requiring them to take pills regularly, which could prevent them from voluntary participation in the study. The participants were explained the testing protocol of the study in detail. Food or drinks containing caffeine or other stimulants, alcohol consumption, and rigorous physical activity were prohibited for at least 24 hours prior to the testing session for all participants.

Physical measurements

Subjects completed the research protocol on two different days (Day 1 and Day 2) with a 48-hour interval, to avoid any possible negative effects of physiological, neurophysiological and fatigue factors on the study. Each test day consisted of two sessions, separated by 20 min rest in the supine position. The first session was a sham intervention (control) (0 Hz, 0 mm vibration), and the second was WBV or LV intervention (50 Hz, 4 mm vibration). All tests were performed by the same group of researcher at the same time of the day (13:00 to 16:00) to avoid the effect of circadian rhythms on the study results. Each session started with a warm-up. Details of the day 1 (LV treatments) and day 2 (WBV treatments) protocols are explained below and in the flow chart (Table 1).

Warm-up exercises: Warm up procedure included 5 min cycling on a cycle ergometer (Monark, Ergomedic-894 E Made in Sweden) at 60 rpm and 50 W.

LV and WBV treatments: LV and WBV were applied using a vertical whole-body vibration platform with a standard dampening mat of 2 cm thickness (Power Plate® Next Generation PRO 5, 2x1A, 2010, USA).

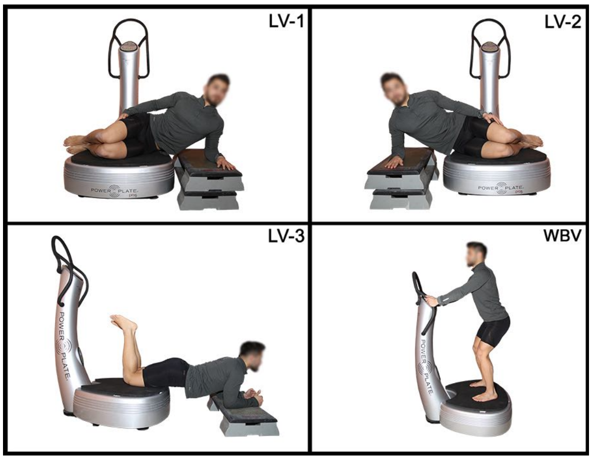

Figure 1. Body positionsusedfor LV and WBV

LV treatments: In this session, the WBV platform was used as a LV source. Subjects positioned their muscles on the WBV platform in three different body postures. The target muscles were subjected to exercise for 2×15 sec with a 1 min passive rest in between. In the sham intervention session, subjects were not exposed to any vibration stimuli (0 Hz, 0 mm). During LV application, subjects were exposed to 50 Hz, 4 mm vibration.

WBV treatments: Subjects performed isometric squat with bare feet at 135° ± 5° knee joint angle on the WBV platform for 6 × 15 sec with 1 min passive rest in between. In the sham intervention session, subjects had no exposure to any vibration stimuli (0 Hz, 0 mm). During the WBV application, subjects were exposed to 50 Hz, 4 mm vibration in the isometric squat position. Knee joint angle was controlled with plastic goniometer (Lafayette Instrument Europe, Richardson Products, INC., Sammons Preston J00240, 12-inch). During the squat position with vibration or no vibration, subjects placed their hands on the WBV device centralized handles for each set.

Countermovement jump (CMJ) test: The CMJ heights were assessed using the Myotest Pro System (Myotest Sport Pro, Sweden). In the CMJ test, participants rapidly squatted down to a self-selected depth and then immediately performed a vertical jump with hands akimbo (Perrier et al., 2011). Strong verbal encouragement was provided to each participant to ensure that each jump was performed with maximal effort. The participants wore the same shoes during both sessions. Participants performed 5 CMJs with 45 sec rest intervals between successive jumps to assess baseline CMJ height. Mean score of the highest 3 CMJ was used in the statistical analyses as the baseline CMJ height. Right after each session, subjects underwent the CMJ test with maximal effort at the 1st, 2nd, 3rd, 4th, 6th, and 8th min to determine the residual effects of LV or WBV treatments.

Figure 1.CMJ test and Myotest device

Table 1. Experimental design flowchart

DAY 1(A)	DAY 1(B)	DAY 2(A)	DAY 2(B)
LV–Sham Intervention (0 Hz, 0 mm)	LV–treatments (50 Hz, 4 mm)	WBV–Sham Intervention (0 Hz, 0 mm)	WBV–treatments (50 Hz, 4 mm)
Warm–up 5 min, on a cycling ergometer at 50 W, 60 rpm	Warm–up 5 min, on a cycling ergometer at 50 W, 60 rpm	Warm–up 5 min, on a cycling ergometer at 50 W, 60 rpm	Warm–up 5 min, on a cycling ergometer at 50 W, 60 rpm
3 min passive rest	8 min passive rest	3 min passive rest	8 min passive rest
Pre–test 5 × CMJ with max effort with 45 sec rest		Pre–test 5 × CMJ with maxeffort with 45 sec rest	
2 min passive rest		2 min passive rest	
2 × 15 sec with 1 min rest, right lateral side of the femoral area	2 × 15 sec with 1 min rest, right lateral side of the femoral area	6×15 sec static squat at 135º±5º knee anglewith 1 min rest	6×15 sec static squat at 135º±5º knee anglewith 1 min rest
1 min rest	1 min rest		
2 × 15 sec with 1 min rest, left lateral side of the femoral area	2 × 15 sec with 1 min rest, left lateral side of the femoral area		
1 min rest	1 min rest		
2 × 15 sec with 1 min rest, quadriceps femoris	2 × 15 sec with 1 min rest, quadriceps femoris		
CMJ tests at 1st, 2nd, 3rd, 4th, 6th, and 8th min	CMJ tests at 1st, 2nd, 3rd, 4th, 6th, and 8th min	CMJ tests at 1st, 2nd, 3rd, 4th, 6th, and 8th min	CMJ tests at 1st, 2nd, 3rd, 4th, 6th, and 8th min

Analysis of data

IBM SPSS Statistics for Windows version 22 was used for the data analysis. Normality assumption for residuals in repeated measures was tested using Shapiro-Wilk test. Two-way repeated measures ANOVA was used to assess whether changes in CMJ height after vibration treatments across time, had a different change pattern (interaction effect of Treatment × Time) compared to control treatment (no vibration). One-way repeated measures ANOVA with post hoc LSD tests were used to assess possible differences in CMJ heights between pre-test and different recovery time points of vibration treatments and control treatments. To avoid loss of statistical power, no confidence interval adjustment was performed for multiply comparisons (Perneger, 1998). Sphericity assumption was checked using Mauchly's Sphericity test. Paired Student's t-tests were used to compare the net effects of vibration treatments ("WBV – control treatment" versus "LV – control treatment") on CMJ height, at comparable time points during recovery. Statistical significance level was set at $p \leq 0.05$ for all analyses.

RESULTS

Descriptive statistics of participants are demonstrated in Table 2.

Table 2. Descriptive statistics of participants (n=32)

	Mean	SD
Age (year)	22.3	3.2
Height (cm)	174.8	6.1
Mass (kg)	73.1	6.8
General Training Age (year)	10.3	4.4
Training Volume (h/wk)	9.5	4.3

H: hour; wk: week; SD: standart deviation

Results of 2 × 7 Two Factor (Treatment [Vibration, Control] × Time [Pre-test, 1, 2, 3, 4, 6, 8. min]) Repeated Measures ANOVAs showed that change pattern in CMJ height across time for both WBV ($p = 0.27$; $n_p^2 = 0.04$) and LV ($p = 0.57$; $n_p^2 = 0.03$) were similar to control treatment (no vibration). These findings indicated that WBV and LV had no significant extra effect on CMJ height when compared to effects of control treatments. Effects of control treatments are demonstrated in Table 3.

Table 3. Change patterns in CMJ height after control treatments performed at 0 Hz, 0 mm vibration (n=32)

	Time (min)	**p**	**Δ (cm)**	**SE (cm)**
After Control Treatment for WBV (CMJ Pre-test: 40.1 ± 4.1 cm)	1	<0.001*	3.01	0.31
	2	<0.001*	2.14	0.30
	3	<0.001*	1.78	0.31
	4	<0.001*	1.47	0.38
	6	<0.001*	1.39	0.33
	8	<0.001*	1.50	0.41
After Control Treatment for LV (CMJ Pre-test: 39.5 ± 3.9 cm)	1	<0.001*	2.07	0.47
	2	0.003*	1.41	0.44
	3	0.024*	1.20	0.50
	4	<0.001*	1.42	0.39
	6	0.004*	1.21	0.39
	8	0.027*	1.08	0.47

*p ≤ 0.05; Δ: Reduction relative to pre-test score, min: minute; CMJ: Counter-Movement Jump; WBV: Whole Body Vibration; LV: Local Vibration; Time: Time passed after the cessation of control treatment; SE: Standard Error

Additionally, when net effects of vibration treatments were compared, no significant difference was detected in CMJ height changes (Δ) between WBV and LV at any of the testing time points (Table 4).

Table 4. Comparison between mean net effects of WBV and LV on CMJ heights (n = 32)

	Net Effects(cm)				**95% CI for Δ (cm)**	
Time (min)	**WBV**	**LV**	**p**	**Δ (cm)**	**Lower**	**Upper**
1	0.75	−0.24	0.075	0.99	−0.11	2.09
2	0.42	−0.42	0.172	0.84	−0.39	2.07
3	0.24	0.06	0.758	0.18	−1.01	1.37
4	0.10	−0.23	0.539	0.34	−0.77	1.45
6	−0.07	0.01	0.871	−0.07	−0.96	0.82
8	0.44	0.53	0.810	−0.09	−0.85	0.67

Net Effects: (WBV – Control Treatment) or (LV – Control Treatment); Δ: Mean difference between net effects of WBV and LV, min: minute; WBV: Whole Body Vibration; LV: Local Vibration; Time: Time passed after the cessation of related treatment.

DISCUSSION

Vibration exercise is a novel exercise modality, which is used in athletes and general population to improve muscle strength and power, improve bone density, prevent sarcopenia and falls in the ageing population, and modulate hormone secretion associated with exercise (Rittweger, 2010). The present study aimed to compare effectiveness of WBV and LV treatment on enhancement of CMJ height in well-trained athletes. The most significant finding in this investigation was that an acute session of WBV and LV reduced CMJ heights to a similar extent when compared to control (sham) treatments. These similar change patterns indicated that reductions in CMJ heights in WBV and LV sessions were resulted from isometric body postures during the treatments. In other saying, net effects of WBV and LV on CMJ were insignificant. It is difficult to explain why sham interventions led to reductions in CMJ height.

These results do not support our hypotheses. However, we concluded that WBV platform can be safely used as an LV exercise equipment, since our subjects experienced no negative effects such as headaches, joint or muscle pain, dizziness, visual impairment, hearing loss, erythema, itching, and edema of the legs during vibration treatments (Dolny et al., 2008).

Many studies have reported that acute WBV leads to increase in jump height and power after vibration treatment (Cardinale et al., 2003; Dallas et al., 2015; Rittweger et al., 2003; Issurin et al., 1999; Cormie et al., 2006; Torvinen et al., 2002; Bazett-Jones et al., 2008; Bullock et al., 2008). On the other hand, a limited number of studies have reported no effect or even a decline (Rittweger, 2010; Cochrane et al., 2004; Gerodimos et al., 2010; Kurt et al., 2015; Cronin et al., 2008). The contradictory results in these studies may have been caused by load parameters of the vibration exercises such as frequency, amplitude, displacement, body position, duration of thetreatment, rest timeand training or health status of the subjects (Adams et al., 2009; Bazett-Jones et al., 2008).

It is reported that low frequency and low amplitude vibration treatment is a safe and effective exercise intervention (Cardinale et al., 2003). Cardinale and Lim (2003) argued that WBV with low frequency (20 Hz, 4 mm) increases squat jump (SJ) and CMJ height. However, WBV with high frequency (40 Hz, 4 mm) decreases squat jump and CMJ height. On the other hand, Bazzet-Jones et al. (2008) reported that 40-50 Hz and 2-4 mm WBV treatment is more effective in increasing CMJ performance compared to 30-35 Hz and 2-4 mm vibration treatment. Rønnestad (2009) suggested that WBV with 50 Hz, and 3 mm is superior to 20-35 Hz and 3 mm, in increasing SJ height. We realize that although in our study, the vibration frequency and amplitude were similar to those in the above studies, the duration of the vibration treatments was too short to achieve any performance change. A further study could be planned with 50 Hz, 4 mm, and 30-60 sec vibration treatments to compare the effectiveness of LV and WBV treatments on CMJ height.

Another important factor in the study of vibration exercises is the training status of the athletes. Some researchers argued that well-trained individuals show acute improvement in force generating capacity (Bosco et al., 1999), and untrained subjects show an acute decrease following similar vibration exercise protocol (Bullock et al., 2008; de Ruiter et al., 2003; Delecluse et al., 2005). Bullock et al. (2008)and Delecluse et al. (2005) argued that well-trained athletes, especially those accustomed to high-intensity stretch-shortening activities, have fast-twitch muscle fibers that have no scope for further performance improvement; this is due to already existing high levels of reflex sensitivity, fast-twitch fiber recruitment, and motor neuron excitability. In addition, the stiffer muscle-tendon units of athletes compared to untrained individuals could be another reason for no improvement, since stiffer muscle-tendon units minimize muscle length changes during WBV, reducing transmission of the vibratory stimulus tolerated body parts and resulting in a lower WBV load. This implies that performance enhancement, especially that related to speed-strength activities in well-trained athletes via WBV is more subtle than in untrained individuals.

Another way of treatment by vibration is local vibration. Formerly, local vibration was applied to the muscle belly or tendon (Issurin et al., 1999). Presently, however, segmental biomechanical muscle stimulation (BMS) devices use local stimulation rather than whole body stimulation (Peer et al., 2009). Siegmund et al. (2014) reported that BMS is useful for improvement of lower back and hamstring flexibility, as well as perceived stiffness. Issurin et al. (1994) and Cronin et al. (2008) proposed that three potential mechanisms could explain the benefits of local vibration treatments: a) increase in pain threshold, b) increase in blood flow with a commensurate increase in temperature, and c) induced relaxation of the stretched muscle.

A familiarization session for the subjects was not included in the present study. Results observed in the present study may have also been caused due to lack of familiarization session. Further studies should examine the effects of LV and WBV on CMJ performance in well-trained athletes. More research is also necessary to determine the appropriate body position, frequency-amplitude of treatment, and time of exposure to the vibration.

Although no improvement in CMJ height was observed, we concluded that the Power Plate WBV platform could be safely used as LV treatment source, without adverse effects.

CONCLUSION AND SUGGESTION

On the basis of the obtainedresults, it can be said that WBV and LV were not effective methods to enhance the CMJ performance of well-trained athletes. But, WBV platform can be safely used as LV exercise equipment since no adverse effect was observed.

Declaration of conflicting interests

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REFERENCES

Abercromby, A.F., Amonette, W.E., Layne, C.S., McFarlin, B.K., Hinman, M.R., Paloski, W.H. (2007). Variation in neuromuscular responses during acute whole-body vibration exercise. *Medicine & Science in Sports & Exercise*, 39: 1642-1650.

Adams, J.B., Edwards, D., Serravite, D.H., Serviette, D., Bedient, A.M. (2009). Huntsman E, et al. Optimal frequency, displacement, duration, and recovery patterns to maximize power output following acute whole-body vibration. *The Journal of Strength & Conditioning Research*, 23: 237-245.

Bagheri, J., van den Berg-Emons, R.J., Pel, J.J., Horemans, H.L., Stam, H.J. (2012). Acute effects of whole-body vibration on jump forceand jump rate of force development: A comparative study of different devices. *The Journal of Strength and Conditioning Research*, 26: 691-696.

Bazett-Jones, D.M., Finch, H.W., Dugan, E.L. (2008). Comparing the effects of various whole-body vibration accelerations on counter-movement jump performance. *Journal of Sports Science and Medicine*, 7: 144-150.

Behm, D.G., Chaouachi, A. (2011). A review of the acute effects of static and dynamic stretching on performance. *European Journal of Applied Physiology*, 111: 2633-2651.

Bosco, C., Cardinale, M., Tsarpela, O., Colli, R., Tihanyi, J., Duvillard, V., Viru, A. (1998). The influence of whole body vibration on jumping performance. *Biology of Sport*, 15: 157-164.

Bosco, C., Colli R, Introini E, Cardinale M, Tsarpela O, Madella A, Tihanyi J, Viru A. (1999). Adaptive responses of human skeletal muscle to vibration exposure. *Clinical Physiology*, 19: 183-187.

Bullock, N., Martin, D.T., Ross, A., Rosemond, C.D., Jordan, M.J., Marino, F.E. (2008). Acute effect of whole-body vibration on sprint and jumping performance in elite skeleton athletes. *The Journal of Strength & Conditioning Research*, 22: 1371-1374.

Cardinale, M., Bosco, C. (2003). The use of vibration as an exercise intervention. *Exercise and Sport Sciences Reviews*, 31: 3-7.

Cardinale, M., Erskine, J.A. (2008). Vibration training in elite sport: Effective training solution or just another fad? *International Journal of Sports Physiology and Performance*, 3: 232-239.

Cardinale, M., Lim, J. (2003). The acute effects of two different whole body vibration frequencies on vertical jump performance. *Medicina Dello Sport*, 56: 287-292.

Cochrane, D.J. (2011). The potential neural mechanisms of acute indirect vibration. *Journal of Sport Science and Medicine*, 10: 19-30.

Cochrane, D.J. (2011). Vibration exercise: The potential benefits. *International Journal of Sports Medicine,* 32: 75-99.

Cochrane, D.J., Legg, S.J., Hooker, M.J. (2004). The short-term effect of whole-body vibration training on vertical jump, sprint, and agility performance. *The Journal of Strength &*

Conditioning Research, 18: 828-832.

Cochrane, D.J., Stannard, S.R. (2005). Acute whole body vibration training increases vertical jump and flexibility performance in elite female field hockey players. *British Journal of Sports Medicine*, 39: 860-865.

Cormie, P., Deane, R.S., Triplett, N.T., McBride, J.M. (2006). Acute effects of whole-body vibration on muscle activity, strength, and power. *The Journal of Strength and Conditioning Research*, 20: 257-261.

Cronin, J., Nash, M., Whatman, C. (2008). The acute effects of hamstring stretching and vibration on dynamic knee joint range of motion and jump performance. *Physical Therapy in Sport*, 9: 89-96.

Dadebo, B., White, J., George, K.P. (2004). A survey of flexibility training protocols and hamstring strains in professional football clubs in England. *British Journal of Sports Medicine*, 38: 388-394.

Dallas, G., Kaimakamis, V., Melos, V., Parasidis, G. (2012). Acute effect of whole-body vibration combined with stretching on bridge performance in artistic gymnasts. *Journal of Biology of Exercise,* 8: 47-57.

Dallas, G., Paradisis, G., Kirialanis, P., Mellos, V., Argitaki, P., Smirniotou, A. (2015). The acute effects of different training loads of whole body vibration on flexibility and explosive strength of lower limbs in divers, *Biology of Sport*, 3; 235-241.

De Ruiter, C.J., van der Linden, R.M., van der Zijden, M.J., Hollander, A.P., de Haan, A. (2003). Short-term effects of whole-body vibration on maximal voluntary isometric knee extensor force and rate of force rise. *European Journal of Applied Physiology*, 88: 472-475.

Delecluse, C., Roelants, M., Diels, R., Koninckx, E., Verschueren, S. (2005). Effects of whole-body vibration training on muscle strength and sprint performance in sprint-trained athletes. *International Journal of Sports Medicine*, 26: 662-668.

Delecluse, C., Roelants, M., Verschueren, S. (2003). Strength increase after whole-body vibration compared with resistance training. *Medicine & Science in Sports & Exercise*, 35: 1033-1041.

Dolny, D.G., Reyes, G.F. (2008). Whole body vibration exercise: training and benefits. *Current Sports Medicine Reports*, 7(3): 152-157.

Drummond, M.D., Couto, B.P., Augusto, I.G., Rodrigues, S.A., Szmuchrowski, L.A. (2014). Effects of 12 weeks of dynamic strength training with local vibration. *European Journal of Sport Science*, 14: 695-702.

Fagnani, F., Giombini, A., Di Cesare, A., Pigozzi, F., Di Salvo, V. (2006). The effects of a whole-body vibration program on muscle performance and flexibility in female athletes. *American Journal of Physical Medicine & Rehabilitation*, 85: 956–962.

Gerodimos, V., Zafeiridis, A., Karatrantou, K., Vasilopoulou, T., Chanou, K., Pispirikou, E. (2010). The acute effects of different whole-body vibration amplitudes and frequencies on flexibility and vertical jumping performance. *Journal of Science and Medicine in Sport*, 13: 438-443.

Giorgos, P., Elias, Z. (2007). Effects of whole-body vibration training on sprint running kinematics and explosive strength performance. *Journal of Sports Science and Medicine*, 6: 44-49.

Hagbarth, K.E., Eklund, G. (1996). Tonic vibration reflexes (TVR) in spasticity. *Brain Research*, 2: 201-203.

Issurin, V.B., Liebermann, D.G., Tenebaum, G. (1994). Effect of vibratory stimulation on maximal force and flexibility. *Journal of Sports Sciences*, 12: 561-566.

Issurin, V.B., Tenenbaum, G. (1999). Acute and residual effects of vibratory stimulation on explosive strength in elite and amateur athletes. *Journal of Sports Sciences*, 17: 177-182.

Kurt, C. (2015). Alternative to traditional stretching methods for flexibility enhancement in well-trained combat athletes: local vibration versus whole-body vibration. *Biology of Sport*, 32: 225-233.

Kurt, C., Pekünlü, E. (2015). Acute effect of whole body vibration on isometric strength, squat jump, and flexibility in well-trained combat athletes. *Biology of Sport*, 32: 115-122.

Luo, J., McNamara, B., Moran, K. (2005). The use of vibration training to enhance muscle strength and power. *Sports Medicine*, 35: 23-41.

Mahieu, N.N., Witvrouw, E., Van de Voorde, D., Michilsens, D., Arbyn, V., Van den, Broecke W. (2006). Improving strength and postural control in young skiers: whole-body vibration versus equivalent resistance training. *Journal of Athletic Training*, 41: 286-293.

Marin, P.J., Bunker, D., Rhea, M.R., Ayllon, F.N. (2009). Neuromuscular activity during whole-body vibration of different amplitudes and foot wear conditions: Implications for prescription of vibratory stimulation. *The Journal of Strength & Conditioning Research*, 23: 2311-2316.

Peer, K.S., Barkley, J.E., Knapp, D.M. (2009). The acute effects of local vibration therapy on ankle sprain and hamstring strain injuries. *The Physician and Sportsmedicine*, 37: 31-38.

Perneger, T.V. (1998). What's wrong with Bonferroni adjustments. *British Medical Journal*, 316: 1236-1238.

Perrier, E.T., Pavol, M.J., Hoffman, M.A. (2011). The acute effects of a warm-up including static or dynamic stretching on countermovement jump height, reaction time, and flexibility. *The Journal of Strength & Conditioning Research*, 25: 1925-1931.

Petit, P-D., Pensini, M., Tessaro, J., Desnuelle, C., Legros, P., Colson, S.S. (2010). Optimal whole-body vibration settings for muscle strength and power enhancement in human knee extensors. *Journal of Electromyography and Kinesiology*, 20: 1186-1195.

Rehn, B., Lidstrom, J., Skoglund, J., Lindstrom, B. (2007). Effects on leg muscular performance from whole-body vibration exercise: A systematic review. *Scandinavian Journal of Medicine & Science in Sports*, 17: 2-11.

Rittweger, J. (2010). Vibration as an exercise modality: How it may work, and what its potential might be. *European Journal of Applied Physiology*, 108: 877-904.

Rittweger, J., Mutschelknauss, M., Felsenberg, D. (2003). Acute changes in neuromuscular excitability after exhaustive whole body vibration exercise as compared to exhaustion by squatting exercise. *Clinical Physiology and Functional Imaging*, 23: 81-86.

Roelants, M., Verschueren, S.M., Delecluse, C., Levin, O., Stijnen, V. (2006). Whole-body-vibration-induced increase in leg muscle activity during different squat exercises. *The Journal of Strength & Conditioning Research*, 20: 124-129.

Rønnestad, B.R. (2009). Acute effects of various whole-body vibration frequencies on lower-body power in trained and untrained subjects. *The Journal of Strength & Conditioning Research*, 23: 1309-1315.

Samson, M., Button, D.C., Chaouachi, A., Behm, D.G. (2012). Effects of dynamic and static stretching within general and activity specific warm-up protocols. *Journal of Sport Science and Medicine*, 11: 279-285.

Savelberg, H.H.C.M., Keizer, H.A., Meijer, K. (2007). Whole-body vibration induced adaptation in knee extensors; consequences of initial strength, vibration frequency, and joint angle. *The Journal of Strength & Conditioning Research*, 21: 589-593.

Siegmund, L.A., Barkley, J.E., Knapp, D., Peer, K.S. (2014). Acute effects of local vibration with biomechanical muscle stimulation on low-back flexibility and perceived stiffness. *Athletic Training & Sports Health Care*, 6: 37-45.

Torvinen, S., Kannu, P., Sievänen, H., Järvinen, T.A., Pasanen, M., Kontulainen, S., Järvinen TL, Järvinen M, Oja P, Vuori I. (2002). Effect of a vibration exposure on muscular performance and body balance. Randomized cross-over study. *Clinical Physiology And Functional Imaging*, 22: 145-152.

Turner, A.P., Sanderson, M.F., Attwood, L.A. (2011). The acute effect of different frequencies of whole-body vibration on countermovement jump performance. *The Journal of Strength & Conditioning Research*, 25: 1592-1597.