The effects of vibration on explosive and reactive strength when applying individualized vibration frequencies

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Abstract
The aim of this study was to assess the effects of 8 weeks of whole-body vibrations on explosive and reactive leg strength. Thirty-three physically active students took part in the study and were randomly assigned to an individualized-vibration group, a fixed-vibration group or a control group. The frequency of vibration was set to 30 Hz for the fixed-vibration group, whereas the frequency for the individualized-vibration group was determined by monitoring the participants’ EMGrms activity. The participants in the two vibration groups were exposed three times a week for 8 weeks to a series of 10 1-min whole-body vibrations with a 1-min pause between series of vibrations and a 4-min pause after the first five series of vibrations. Jump height in the squat jump increased significantly in all three groups (by 11% for the individualized-vibration group, \( p = 0.001 \); by 3% for the fixed-vibration group, \( p = 0.011 \); and by 2% for the control group, \( p = 0.006 \)), but countermovement jump height was not affected. In continuous rebound jumps by the individualized-vibration group, jumping height increased by 22% (\( p = 0.006 \)) and power increased by 18% (\( p = 0.002 \)). The results of this study suggest that the use of an individualized vibration frequency produces a greater response from the neuromuscular system and is more beneficial than vibrations at a fixed pre-selected frequency.

Keywords: Individual vibration frequency, explosive-reactive strength, vertical jumps, mechanical power

Introduction
Over the last decade, many researchers have studied the effects of mechanical vibration on the physical performance of trained and untrained people. In most cases, the vibration was applied to the muscles of the lower extremity in a standing crouched position, so-called “whole-body vibration”. Whole-body vibration assumes that the vibration frequency induced by a motor to the platform elicits a tonic vibration reflex similar to the direct or indirect application of vibration on muscles or tendons. Research has focused extensively on both the acute (Bosco, Cardinale, & Tsarpela, 1999a; Bosco et al., 2000; De Ruiter, Van der Linden, Van der Zijeden, Hollander, & De Haan, 2003a; Rittweger, Mutschelknauss, & Felsenberg, 2003; Torviren et al., 2002a, 2002c) and chronic (Bosco et al., 1998; Delecude, Roelants, & Verschueren, 2003; De Ruiter, Van Rask, Schilperoort, Hollander, & De Haan, 2003b; Roelants, Delecude, Goris, & Verschueren, 2004a; Roelants, Delecude, & Verschueren, 2004b; Torviren et al., 2002b, 2003) effects of vibrations using different types of vibratory methods. It is generally agreed that several factors influence the acute, residual, and chronic effects of vibration exposure (Luo, McNamara, & Moran, 2005). Vibration characteristics (i.e. vibratory application, amplitude, frequency, and exercise protocols) are the main factors influencing neuromuscular performance (Luo et al., 2005). Basically, the intensity of vibration load on the neuromuscular system is determined by the vibration frequency and amplitude. In most studies, the frequency of the applied vibration was between 20 and 40 Hz, and the amplitude was between 1 and 5 mm. In the aforementioned studies, however, the effect of vibration training was used without individualizing the applied vibration frequency to each participant. The EMGrms recorded in the biceps brachii of boxers shows neural activity during vibration treatment of more than double that under normal conditions (Bosco et al., 1999a). It would appear that a high-frequency vibration may decrease the harmonic synchronization of the motor units, which
then has a detrimental influence on neuromuscular performance (Martin & Park, 1997). Moreover, individuals react differently to the applied frequency – that is, each individual has a different optimum frequency of vibration that elicits the greatest reflex response during whole-body vibration (Bongiovanni, Hagbarth, & Stjernberg, 1990; Cardinale & Bosco, 2003; Cardinale & Lim, 2003).

Using the EMG muscle response during vibration exposure as a neuromuscular index appears to be appropriate for identifying an individual’s optimum frequency of stimulation. Therefore, an individualized vibration frequency could be more effective than a fixed vibration frequency in improving the dynamic strength of the muscles of the lower extremity, especially in trained individuals, and a shorter vibration intervention could be sufficient to elicit significant improvement in measures of muscle strength. Furthermore, the reflex response, defined as tonic vibration reflex, induced within the muscle that is being vibrated (Eklund & Hagbarth, 1966) can be altered by modifying the joint angle (Johnston, Bishop, & Coffey, 1970). It is likely that an increase in tonic vibration reflex reflects an improvement in both the static and dynamic sensitivity of the muscle spindles in the lengthened muscle (Johnston et al., 1970). In addition, Caldwell and colleagues (Caldwell, Jamison, & Lee, 1993) have suggested that there may be preferential recruitment of certain motor units at certain positions or angles.

During whole-body vibration, assuming that the neuromuscular response is modulated by Ia-afferents (Delecluse et al., 2003) similar to the vibration stimulus applied directly to a muscle (Eklund & Hagbarth, 1966), the sensitivity of muscle spindles in the lengthened muscle could be influenced by a vibratory treatment. A recent study in which whole-body vibration was applied at different knee angles during acute exposure revealed a greater neuromuscular response at a small knee angle of about 10–15° (squat to fully 40°) than at a larger knee angle of 30–35° (Abercromby et al., 2007). Consequently, mechanical vibration may affect jumping performance differently during chronic exposure when the vertical jumps are performed with different muscle contractions and angular displacement.

Materials and methods

Participants and study design

Thirty-three physically active male and female participants (sports science students) were randomly assigned to an individualized-vibration group, a fixed-vibration group or a control group. However, only 9 participants in the individualized-vibration group (5 females/4 males; mean age 22.0 years, \( s = 0.9 \); height 1.70 m, \( s = 0.07 \); body mass 66.3 kg, \( s = 10.6 \)), 10 in the fixed-vibration group (5 females/5 males; age 21.9 years, \( s = 1.5 \); height 1.73 m, \( s = 0.07 \); body mass 66.2 kg, \( s = 8.4 \)), and 11 in the control group (5 females/6 males; age 22.0 years, \( s = 1.3 \); height 1.75 m, \( s = 0.08 \); body mass 65.6 kg, \( s = 8.3 \)) completed all test sessions. All of the participants were engaged in systematic physical activities (gymnastics, swimming, and track and field activities) at least three times per week. The participants provided written informed consent before participating and the study was approved by the Ethics Committee of L’Aquila University.

Estimation of optimum vibration frequency

The participants were exposed to a vertical sinusoidal whole-body vibration using a vibratory platform (Nemes-Lsb, Bosco-System, Rieti, Italy). The participants stood on a platform at an angle of 90° between the lower and upper leg, while grasping a railing in front of them (Figure 1).
The peak-to-peak amplitude of the vibration was about 2 mm. The vertical component of the acceleration was measured using an accelerometer (Type ET-Acc-02, Ergotest Technology, Langesund, Norway) placed in the middle of the vibration platform during a progressive incremental frequency protocol from 20 to 55 Hz. The accelerations in this test ranged from 1.1 to 53.6 m · s⁻² (Figure 2).

The frequency of the vibrations was determined for each member of the individualized-vibration group by monitoring the EMGrms activity of the vastus lateralis muscle during trials performed at different frequencies. The participants performed an isometric half-squat in the following conditions: no vibration (i.e., 0 Hz), and at 20, 25, 30, 35, 40, 45, 50, and 55 Hz in random order with a 4-min pause between trials, with each trial lasting 20 s. The highest neuromuscular response (EMGrms activity) recorded during the trials was used for the vibration training (Figure 3). In a comparable group of participants, the day-to-day reliability of the individual vibration frequency was 0.92 (coefficient of variation = 6.2).

The EMG sensors and accelerometer were connected to a data collection unit (MuscleLab-Ergotest Technology, Langesund, Norway), which, in turn, was connected to a personal computer via the USB port.

Vibration intervention

The members of the two vibration groups were exposed to whole-body vibration three times a week (on Monday, Wednesday, and Friday) for 8 weeks. During each training session they underwent 10 series of 1-min (10 × 1) whole-body vibrations with a 1-min pause between series and a 4-min pause after the first five series of vibrations (5 × 1) (Table I).

The vibration frequency was set individually for each participant (for the individualized-vibration group) or fixed at 30 Hz (for the fixed-vibration group). Participants in the control group stood on the vibration platform in exactly the same body position with knees flexed to 90°. Control participants were not exposed to vibration.

Test procedures

The participants were tested on four occasions at the same time of day, and they were requested to refrain from any tiring physical activity in the 2 days before the test. Measurements were made before starting the whole-body vibration intervention, after 4 weeks of treatment, after 8 weeks of treatment, and then 1 week after the end of vibration treatment.

Each test session began with measurement of anthropometric characteristics. Next, each participant completed a 10-min warm-up (6 min running on a treadmill at a speed of 6 km · h⁻¹ and 4 min stretching) before performing a series of vertical

![Figure 2. Acceleration of the vibrating plate as the frequency of vibration was increased by 5 Hz every 5 s from 20 to 55 Hz. The acceleration values ranged from 0.1 to 5.5 g (where g is the acceleration due to gravity, 9.81 m · s⁻²).](image)

![Figure 3. The EMGrms of the vastus lateralis recorded during different vibration frequencies normalized to the baseline isometric value. The participants performed an isometric half-squat in the following conditions: no vibration, and 20, 25, 30, 35, 40, 45, 50, and 55 Hz vibration frequencies in random order. The black bars indicate the highest neuromuscular responses recorded. Example for participant A and for participant B.](image)
Table I. Characteristics of whole-body vibration treatment.

<table>
<thead>
<tr>
<th>Training volume and intensity of the vibration treatment</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Volume</strong></td>
<td></td>
</tr>
<tr>
<td>Total duration of vibration in one session (min)</td>
<td>10</td>
</tr>
<tr>
<td>Number of series</td>
<td>10</td>
</tr>
<tr>
<td>Duration of one series (s)</td>
<td>60</td>
</tr>
<tr>
<td>Number of training sessions in one week</td>
<td>3</td>
</tr>
<tr>
<td>Total number of training sessions</td>
<td>24</td>
</tr>
<tr>
<td>Total duration of vibration in 8 weeks (min)</td>
<td>240</td>
</tr>
<tr>
<td><strong>Intensity</strong></td>
<td></td>
</tr>
<tr>
<td>Rest period after the first five series (min)</td>
<td>4</td>
</tr>
<tr>
<td>Rest period between series (s)</td>
<td>60</td>
</tr>
<tr>
<td>Rest period between two training sessions (days)</td>
<td>1–2</td>
</tr>
<tr>
<td>Vibration amplitude (mm)</td>
<td>~2</td>
</tr>
<tr>
<td>Vibration frequency (Hz)</td>
<td>From 20 to 45</td>
</tr>
</tbody>
</table>

Jumps. Participants performed the squat jump, the countermovement jump, and the continuous rebound jumps on a resistive platform (Ergojump) (Bosco, Luhtanen, & Komi, 1983). Maximum knee flexion in the squat jump and the countermovement jump (≈90°) was measured using an electrogoniometer connected to a Muscle-Lab. In the continuous rebound jumps (duration 10 s), the participants were instructed to jump as high as possible with the shortest ground contact time. The participants were also instructed to place their hands on their waist and to keep their knees extended as much as possible during the test. Three repetitions each of squat jumps and countermovement jumps were performed, and the maximum vertical jumping height was calculated using a platform that has been described elsewhere (Bosco et al., 1983). The continuous rebound jumps were performed twice in each test session. Contact time and flight time were measured and power was calculated.

To avoid a small countermovement during the squat jump, a string with metal stops was placed under the gluteus of the participant at a position corresponding to a knee angle of 90° (measured using an electrogoniometer connected to a Muscle-Lab). If the string moved during execution of the jump, the jump was deemed to have been incorrectly performed and was therefore repeated.

The height of rise of the centre of mass in the squat jump and in the countermovement jump was determined by the flight time according to the method of Asmussen and Bonde-Petersen (1974), and used in order to analyse the explosive strength characteristics of the leg muscles as reported elsewhere (Bosco et al., 1998, 2000; Delecluse et al., 2003; Torvinen et al., 2002a, 2002b, 2002c). Jump height, \( h \), was calculated using

\[
    h = g \frac{t_f^2}{8},
\]

where \( t_f \) is the flight time and \( g \) is the acceleration due to gravity (9.81 m · s\(^{-2}\)).

The continuous rebound jump, which involves rebounding vertically, is considered an indicator of explosive strength in a stretch–shortening cycle, with reactive strength capacities similar to a drop jump (Horita, Komi, Hamalainen, & Avela, 2003; Young, Wilson, & Byrne, 1999a, 1999b). During the jumps, flight time and contact time were measured and used to calculate jump height (Asmussen & Bonde-Petersen, 1974).

Mean power was calculated from contact time and flight time (Bosco et al., 1983), and also used to estimate the explosive strength during a ballistic movement that involved a stretch–shortening cycle of the legs (Chelly & Denis, 2001). The centre of mass displacement, flight time, and contact time in each single jump, as well as the overall number of jumps performed, were also recorded. Mean power, \( P \) (in W · kg\(^{-1}\)), was calculated as follows:

\[
    P = (g^2 \frac{T_f}{10})/4n(10 - T_d),
\]

where \( g \) is the acceleration due to gravity (9.81 m · s\(^{-2}\)), \( T_f \) is the total performance time (in seconds), \( n \) is the number of jumps, and \( T_d \) is the total flight time of all jumps.

The day-to-day reliability of jumping measurements, tested in a comparable group of participants by Markovic and colleagues (Markovic, Dizdar, Jukic, & Cardinale, 2004), was 0.97 (coefficient of variation = 3.3) for the squat jump and 0.98 (coefficient of variation = 2.8) for the countermovement jump. In a comparable group of participants, the day-to-day reliability of the continuous rebound jump was 0.94 (coefficient of variation = 2.9) for jump height and 0.95 (coefficient of variation = 2.7) for power.

**EMG analysis**

The EMG activity was recorded using bipolar surface electrodes (inter-electrode distance: 2.0 cm) including an amplifier (gain at 100 Hz: 1000; input impedance: 2 GΩ common mode rejection rate: 100 dB; input noise level (1 kHz band): 20 nV · Hz\(^{-2}\)) and a Butterworth band-pass filter (3-dB low cut-off frequency: 8 Hz; 3-dB high cut-off frequency: 1200 Hz) fixed longitudinally over the muscle belly. The EMG cables were secured (the participants wore a suit next to the skin) to prevent movement artefact.

\[
    h = g \frac{t_f^2}{8},
\]
The pre-amplified EMG signals were first converted to root mean square and then sampled at 100 Hz. The averaged root mean square was expressed as a function of time in millivolts.

Statistical analyses

Conventional statistical methods were employed, including mean values, standard deviations (s), and percentages (%). The effect of intervention time of whole-body vibration (independent variable) on explosive and reactive leg strength (dependent variables: squat jump height, countermovement jump height, together with jump height, power, flight time, and contact time during the continuous rebound jump) was assessed over time by means of the Friedman test in each group and by a Wilcoxon test for within-group comparisons to locate differences. A Bonferroni correction was used to adjust the P-value in relation to the number of contrasts that were performed. The comparisons between groups were made using the Kruskal-Wallis test. The day-to-day reliability of the measurements (three trials on successive days) was calculated using intra-class correlation (Cronbach’s alpha coefficient to determine between-participants reliability) and the coefficient of variation (to determine the within-participant variation) as outlined by Hopkins (2000).

All analyses were executed using the SPSS package (version 12). Statistical significance was set at $P < 0.05$.

Results

During the first weeks of the treatment, two participants in the individualized-vibration group and one from the fixed-vibration group withdrew from the study due to loss of interest. All remaining members of the vibration groups performed on average 23 (96.2%; range 22–24) of the 24 training sessions programmed during the 8-week period, without side-effects or muscle-tendon injuries. The results of 30 participants were analysed for four test sessions (individualized-vibration group, $n = 9$; fixed-vibration group, $n = 10$; control group, $n = 11$).

Explosive strength

Whole-body vibration increased squat jump performance significantly in the individualized-vibration group by 3.1 cm ($s = 2.0$, $P = 0.001$), compared with a slight increase of 0.8 cm ($s = 1.1$, $P = 0.011$) in the fixed-vibration group and of 0.7 cm ($s = 1.1$, $P = 0.006$) in the control group (Figure 4), resulting in a benefit of 11%, 3%, and 2% for the individualized-vibration group, fixed-vibration group, and control group respectively.

In the countermovement jump (Figure 4), none of the groups improved their jumping height significantly (individualized-vibration group, $P = 0.060$; fixed-vibration group, $P = 0.185$; control group, $P = 0.108$).

Reactive strength

The individualized-vibration group showed a significant 4.7 cm ($s = 3.6$) improvement (22%, $P = 0.006$) in jumping height over the vibration treatment, with no effect being observed for the fixed-vibration group ($P = 0.195$) or the control group ($P = 0.212$) (Figure 5).

The individualized-vibration group increased mechanical power progressively (Figure 5), and statistical significance was reached at one week after the end of the vibration treatment ($6.5 \text{ W} \cdot \text{kg}^{-1}$, Figure 4. Change in jumping height during a squat jump (A) and countermovement jump (B) over time. 0-weeks = before vibration; 4-weeks = after 4 weeks of vibration; 8-weeks = after 8 weeks of vibration; 9-weeks = one week after the end of the vibration treatment. Values are means and error bars are standard deviations. **Significant difference from 4-weeks for the fixed-vibration group. ***Significant difference from 4-weeks for the control group. *Significant difference from 0-weeks for the individualized-vibration group. **Significant difference from 4-weeks for the individualized-vibration group.
The increase in mechanical power in the fixed-vibration group was slight (1.1 W · kg⁻¹, s = 1.6; 3%), without reaching statistical significance (P = 0.155). The control group showed a similar non-significant increase in mechanical power one week after the end of the vibration treatment (0.9 W · kg⁻¹, s = 1.6; 2%) (P = 0.183).

Flight time increased significantly in the individualized-vibration group (P = 0.014), whereas contact time did not change significantly in any of the groups (individualized-vibration group, P = 0.162; fixed-vibration group, P = 0.118; control group, P = 0.081) (Figure 6).

Discussion

Fixed whole-body vibration versus individualized whole-body vibration

Whole-body vibration, applied at individual vibration frequencies, produced statistically significant improvements in selected vertical jump performance. Vertical jump performance improved by 11% (P = 0.01) and 22% (P = 0.001) in the individualized-vibration group for squat jump and continuous rebound jumps respectively. The fixed-vibration group and, surprisingly, the control group increased performance in the squat jump by 3% (P = 0.011) and 2% (P = 0.006), respectively. The small but significant improvement in the fixed-vibration group and the control group may be attributed to the participants’ other training that was performed during the vibration intervention, but it is unclear why a significant change was not also found (across all groups) in the countermovement jump and the continuous rebound jump (fixed-vibration group).

These results provide partial support for our hypothesis and are in limited agreement with those of previous studies (Bosco et al., 1998, 1999b; Cochrane, Legg, & Hooker, 2004; Delecluse et al.,
have had about 34% less EMGrms (Figure 3). Participant A had been vibrated at 45 Hz, he would have been about 74% less than the EMGrms activity. An estimated on the basis of EMGrms activity. An important observation was that the optimum frequency selected for whole-body vibration varied between participants. For example, if Participant B had been vibrated at 30 Hz, the EMGrms activity would have been about 74% less than the EMGrms that was observed at 45 Hz, the optimum frequency selected for this individual. As another example, if Participant A had been vibrated at 45 Hz, he would have had about 34% less EMGrms (Figure 3).

The use of the individual vibration frequency

It is unclear whether there is an optimal vibration frequency for all individuals and, if there is, whether that frequency will improve performance more than any other frequency. Unlike the present study, which used individualized frequencies, previous studies used frequencies that were fixed or which increased progressively for each participant during the treatment period. Indeed, whole-body vibration at various vibration frequencies has produced inconsistent results. In some studies, muscle strength increased (Bosco et al., 1998; Delecluse et al., 2003; Paradisis & Zachariogiannis, 2007; Roelants et al., 2004a, 2004b; Russo et al., 2003; Torvinen et al., 2002a, 2002b, 2003), whereas in other studies it was unaffected (Cochrane et al., 2004; Delecluse et al., 2005; De Ruiter et al., 2003b; Ronnestad, 2004; Schlumberger, Salin, & Schmidtbleicher, 2001). We suspect that these inconsistent results could be due to differences among individuals in their sensitivity to vibration frequency. We suggest that the frequency characteristics of whole-body vibration should be prescribed in an individualized fashion similar to exercise prescription for progressive resistance exercise in terms of loads, number of repetitions, and series. There is evidence to suggest, for example, that the determination of optimal dropping height for drop jump training improved performance in vertical jumps more than non-customized training programmes (Bosco & Komi, 1979; Viitasalo & Bosco, 1982). In addition, recent studies have demonstrated that individuals react differently to a similar vibration frequency (Cardinale & Bosco, 2003; Cardinale & Lim, 2003).

In the present study, the individual frequency used during whole-body vibration for each participant was estimated on the basis of EMGrms activity. An important observation was that the optimum frequency selected for whole-body vibration varied between participants. For example, if Participant B had been vibrated at 30 Hz, the EMGrms activity would have been about 74% less than the EMGrms that was observed at 45 Hz, the optimum frequency selected for this individual. As another example, if Participant A had been vibrated at 45 Hz, he would have had about 34% less EMGrms (Figure 3).

Results from previous studies suggest that untrained young males and females (Delecluse et al., 2003; Torvinen et al., 2002a, 2002b, 2003; Verschuuren et al., 2004) as well as elderly females (Roelants et al., 2004a, 2004b; Russo et al., 2003; Verschuuren et al., 2004) may benefit the most from whole-body vibration. In addition, performance in vertical jumps has been shown to improve significantly in young adults (Delecluse et al., 2003; Torvinen et al., 2002a, 2002b, 2003), with the greatest change (19%) seen in post-menopausal women (Roelants et al., 2004b). In contrast, whole-body vibration produced little improvement in vertical jump height in trained and physically active individuals (Delecluse et al., 2005; De Ruiter et al., 2003b). These data suggest that the potential to improve performance is associated with training history.

Although the participants in the present study were physically active males and females, they still showed significant improvements in vertical jump height after whole-body vibration when an individualized frequency of vibration was applied. De Ruiter et al. (2003b) used similar participants and used fixed instead of individualized frequency for whole-body vibration. We, like de Ruiter et al. (2003b), did not observe significant improvements in jump height in the fixed-vibration group. Overall, these data suggest that individually selected rather than fixed vibration frequencies may indeed improve physical performance even in previously trained males and females, and that such improvement can be observed over a shorter time as that in sedentary participants.

Effect of whole-body vibration on different types of vertical jump

The second aim of this study was to determine if whole-body vibration produces similar improvements in vertical jumps that use different muscle contractions in the preparatory phase. If whole-body vibration decreases the recruitment threshold of the fast motor units (Romaiguère, Vedel, & Pagni, 1993), then individualized whole-body vibration should increase jumping performance in all three types of vertical jumps, as each type of jump requires rapid muscle activation. It is also possible that whole-body vibration will increase jump height more in both the countermovement and continuous rebound jump than in the squat jump because the stretch reflex evoked in those jumps would increase motor-neuron excitability, and hence jump height (Matthews, 1991). Unexpectedly, we found less improvement in the countermovement jump than in the squat jump. It is likely that the large and relatively slow angular displacement in the countermovement jump did not elicit a stretch reflex, which
is influenced more by whole-body vibration than by voluntary effort. As anticipated, the greatest improvement in jumping height was in the continuous rebound jump, as it has the shortest angular displacement. Although both the countermovement jump and the continuous rebound jump are characterized by a stretch–shortening cycle, the neuromuscular activation in the countermovement jump is different from that in the continuous rebound jump. The countermovement jump is characterized by large angular displacement and slow stretching speed (3–6 rad s⁻¹), while the continuous rebound jump is performed at a fast stretching speed (10–12 rad s⁻¹) and small angular displacement (Bosco et al., 1998). This explanation is supported by the fact that stretch reflex is most capable of accommodating a small length change in the muscle (Matthews, 1991).

In relation to this finding, Nardone and Schieppati (1988) reported that lengthening of the triceps surae resulted in selective recruitment of fast motor units. Since the triceps surae plays a more significant role in the execution of vertical jumps than the knee extensors, which are the dominant muscle group in the countermovement jump (Kovács et al., 1999), this also explains why significantly greater improvement was observed in the continuous rebound jump. In general, the influence of whole-body vibration on physical performance is most marked when movement or strength exertion is performed with short angular displacement and when the muscle stretch is fast.

In conclusion, the present results suggest that chronic whole-body vibration can improve vertical jump performance. Compared with fixed frequencies, individualized vibration frequencies based on the EMG response to whole-body vibration seem to produce greater improvement in vertical jumps, especially those performed with small joint excursions. Whole-body vibration performed at individualized frequencies may improve performance more quickly compared with whole-body vibration at a fixed frequency. Future studies should try to confirm the present results and also determine the mechanisms mediating the performance-enhancing effects of whole-body vibration.

References


