Eur J Appl Physiol (2000) 81: 449–454

ORIGINAL ARTICLE

C. Bosco · M. Iacovelli · O. Tsarpela · M. Cardinale
M. Bonifazi · J. Tihanyi · M. Viru
A. De Lorenzo · A. Viru

Hormonal responses to whole-body vibration in men

Accepted: 8 September 1999

Abstract The aim of this study was to evaluate the acute responses of blood hormone concentrations and neuromuscular performance following whole-body vibration (WBV) treatment. Fourteen male subjects [mean (SD) age 25 (4.6) years] were exposed to vertical sinusoidal WBV, 10 times for 60 s, with 60 s rest between the vibration sets (a rest period lasting 6 min was allowed after 5 vibration sets). Neuromuscular performance tests consisting of counter-movement jumps and maximal dynamic leg presses on a slide machine, performed with an extra load of 160% of the subjects body mass, and with both legs were administered before and immediately after the WBV treatment. The average velocity, acceleration, average force, and power were calculated and the root mean square electromyogram (EMGrms) were recorded from the vastus lateralis and rectus femoris muscles simultaneously during the leg-press measurement. Blood samples were also collected, and plasma concentrations of testosterone (T), growth hormone (GH) and cortisol (C) were measured. The results showed a significant increase in the plasma concentration of T and GH, whereas C levels decreased. An increase in the mechanical power output of the leg extensor muscles was observed together with a reduction in EMGrms activity. Neuromuscular efficiency improved, as indicated by the decrease in the ratio between EMGrms and power. Jumping performance, which was measured using the counter-movement jump test, was also enhanced. Thus, it can be argued that the biological mechanism produced by vibration is similar to the effect produced by explosive power training (jumping and bouncing). The enhancement of explosive power could have been induced by an increase in the synchronisation activity of the motor units, and/or improved co-ordination of the synergistic muscles and increased inhibition of the antagonists. These results suggest that WBV treatment leads to acute responses of hormonal profile and neuromuscular performance. It is therefore likely that the effect of WBV treatment elicited a biological adaptation that is connected to a neural potentiation effect, similar to those reported to occur following resistance and explosive power training. In conclusion, it is suggested that WBV influences proprioceptive feedback mechanisms and specific neural components, leading to an improvement of neuromuscular performance. Moreover, since the hormonal responses, characterised by an increase in T and GH concentration and a decrease in C concentration, and the increase in neuromuscular effectiveness were simultaneous but independent, it is speculated that the two phenomena might have common underlying mechanisms.

Key words EMG · Growth hormone · Jumping performance · Testosterone · Whole-body vibrations

Carmelo Bosco (✉)
Societa Stampa Sportiva, Via G.Guinizzelli,
56-00152 Rome, Italy
e-mail: c.bosco@quipo.it

C. Bosco · A. De Lorenzo
Fondazione "Don Gnocchi",
Università di Roma Tor-Vergata,
Rome, Italy

C. Bosco
Centre for Study and Research of the Italian Track
and Field Association – F.I.D.A.L.,
Rome, Italy

C. Bosco · O. Tsarpela · M. Cardinale
Federazione Italiana Pugilistica,
Rome, Italy

C. Bosco · O. Tsarpela · M. Cardinale · J. Tihanyi
Department of Biomechanics,
Hungarian University of Physical Education,
Budapest, Hungary

M. Iacovelli
Università di Roma La Sapienza,
Rome, Italy

M. Bonifazi
Instituto di Fisiologia Umana,
Universita degli Studi di Siena,
Italy

M. Viru · A. Viru
Institute of Exercise Biology,
University of Tartu, Estonia

Introduction

Recent studies have documented the effect of vibration on the neuromuscular apparatus. Acute treatment with whole-body vibration (WBV) has been shown to increase leg muscle force (F) and power ($\dot{W}$), and movement velocity. After 10 min of vibration treatment the velocity/F and $\dot{W}/F$ curves were shifted to the right (Bosco et al. 1999a). In 12 well-trained boxers, treated with 5 repetitions of 1-min vibration that was applied while their arms were kept in a semi-flexed position, an increase in the mechanical $\dot{W}$ of the arm was observed. The root mean square of the associated electromyogram (EMGrms) did not change following the vibration treatment, but the ratio of EMG/$\dot{W}$ decreased, showing an enhancement of neural efficiency (Bosco et al. 1999b). Apart from these acute effects, vibration may induce chronic adaptation changes in the mechanical behaviour of human skeletal muscles: a daily series of five vertical sinusoidal vibrations lasting 90 s each and imposed for a period of 10 days caused pronounced improvement of jumping performance (Bosco et al. 1998). These results suggest that vibration elicits short-term and long-term neurogenic adaptation. In accordance with this, previous studies have demonstrated a facilitation of the excitability of the patellar tendon reflex by vibration applied to quadriceps muscle (Burke et al. 1996), vibration-induced drive of α-motoneurones via the Ia loop (Rothmuller and Cafarelli 1995), and activation of the muscle spindle receptors (Kasai et al. 1992). However, muscle tissue can also be affected by vibration (Necking et al. 1992). In rats, a vibration-induced enlargement of slow- and fast-twitch fibres has been demonstrated (Necking et al. 1996).

A question arises as to whether vibration effects include adaptive changes and changes in endocrine functions. It has been shown that short-term intensive exercises such as 60-s consecutive jumps (Bosco et al. 1996a), anaerobic cycle exercises (Adlercreutz et al. 1976; Näveri et al. 1985; Buono et al. 1986; Farrell et al. 1987; Brooks et al. 1988; Kraemer et al. 1989; Schwarz and Kindermann 1990) and weight lifting (Kraemer et al. 1990; Schwab et al. 1993) evoke rapid hormonal responses. At the same time, certain relationships seem to exist between plasma concentrations of hormones and short-term performance: athletes with better explosive strength and sprint-running performances have a higher basal concentration of testosterone (T, Kraemer et al. 1995; Bosco et al. 1996b). It has been demonstrated that exercise-induced hormonal responses are significant not only for acute adaptation, but also for triggering long-term training effects (Inoue et al. 1994; Viru 1994; Kraemer et al. 1996). Similarly, the vibration-induced hormonal changes may be significant for chronic improvement of neuromuscular function in repeated exposure to vibration.

The aim of the present study was to test the possibility that WBV induces changes in the plasma concentration of hormones that are known to be associated with the adaptation of muscular activity.

Methods

Subjects

A group of 14 male subjects [mean (SD) age 25.1 (4.6) years, body mass (m_b) 80.9 (12.9) kg, height 177.4 (12.3) cm] voluntarily participated in the study. They were physically active and were engaged in a team sport training program three times a week. Each subject was instructed on the protocol and gave their written informed consent to participate in the experiment, which was approved by the ethical committee of the Italian Society of Sport Science. Subjects with a previous history of fractures or bone injuries were excluded from the study, as were those under the age of 18 years. The protocol consisted of performing jumping and mechanical $\dot{W}$ testing together with electromyographic (EMG) analysis of leg extensor muscles, as well as blood collection for analysis, before and immediately after the 10-min WBV treatment.

Testing procedures

The first blood sample was taken after the measurement of height and m_b. The subjects then performed a 10-min warm-up, consisting of 5 min of bicycling at 25 km/h on a cycle ergometer (Newform s.p.a., Ascoli Piceno, Italy), followed by 5 min of static stretching for the quadriceps and triceps surae muscles.

Jumping measurements

After the warm-up, as well as after the vibration exposure, the subjects performed three trials of a counter-movement jump (CMJ). The flight time (t_f) and contact time (t_c) of each single jump was recorded on a resistive (capacitative) platform (Bosco et al. 1983) that was connected to a digital timer (accuracy ± 0.001 s; Ergojump, Psion XP, MA.GI.CA., Rome, Italy). To avoid unmeasurable work, horizontal and lateral displacements were minimised, and the hands were kept on the hips throughout the test. During CMJ the angular displacement of the knee was standardised so that the subjects were required to bend their knee to approximately 90°. The increase in the centre of gravity above the ground (height in m) was measured from t_f (s) by applying ballistic laws:

$$h = t_f^2 \cdot g \cdot 8^{-1}(\mathrm{m}) \quad (1)$$

where g is the acceleration due to gravity (9.81 m $\cdot$ s^{-2}). The best performance was used for statistical analysis.

Reproducibility of jumping measurements

The reproducibility of the increase in the centre of gravity during CMJ performances was high $r = 0.90$ (Bosco and Viitasalo 1982).

Mechanical $\dot{W}$ measurements

After the jumping test, all of the subjects, who were well accustomed with the exercises, performed maximal dynamic leg-press exercises on a slide machine (Newform s.p.a.) with extra loads of 160% of the subject's m_b, corresponding to 70% of a one-repetition maximum (1RM), with both legs. Five attempts were made with 1-min intervals between each. Since two or three trials were needed to reach a plateau in performance, the last two trials of each set of