NEW TRENDS IN TRAINING SCIENCE: THE USE OF VIBRATIONS FOR ENHANCING PERFORMANCE

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Introduction

The adaptive responses of the human body to training stimuli have been investigated in depth over the past few years. Thanks to the research carried out in different parts of the world, we know that the adaptation to the training stimulus is related to the modification induced by the repetition of daily exercises, which are specific to the movements executed (Edington and Edgerton, 1976). These adaptations are related to the fact that human skeletal muscle is a specialised tissue, which modifies its overall functional capacity in response to regular exercise with high loads (McDonagh and Davies, 1984).

The above-mentioned findings all suggest that resistance exercise can be an effective means of enhancing muscular performance. In this context it should be noted that changes within the muscle itself constitute the most important adaptation to resistance exercise (Sale, 1988; Behm, 1995).

In fact, strength training responses have been shown to be mediated by both neurogenic and myogenic factors (Moritani and De Vries, 1979). Neural adaptations have been shown to be the first changes to occur in the muscle, permitting gains in muscle strength and power in the early stages of a resistance exercise programme in the absence of an increase in the cross-sectional area of the muscle (Behm, 1995; Costill et al. 1979). It has also been demonstrated that specific adaptations occur depending on the training programme implemented (Sale and McDougall, 1981).

Strength training can therefore be considered as a training stimulus, which produces specific adaptations in human skeletal muscles, based upon the protocol, utilised for training. The specificity of training effect from strength work has been underlined by many authors (Sale, 1988; Behm, 1995; Morrisey et al. 1995; Bandy et al. 1990) and the velocity specific effect has been highlighted as the most interesting outcome of resistance exercise programmes. However, even if the mechanisms underlining this velocity specific effect have not been clearly defined, most importance has been given to the neural adaptations such as improved co- ordination, increased activation of the prime mover muscles (Moritani and De Vries, 1979), recruitment and synchronisation.

The aim of most resistance training programmes for elite athletes is to improve the mechanical power output for a given movement, or to enhance speed. In thinking about a boxing punch, a handball throw, a volleyball spike, or a shot putt, these movements involve the exact timing of many muscle groups and are characterised by many coordinative factors. However, boxers, handball and volleyball players and shot putters undergo strength training sessions with the aim of improving their level of performance. Any ideas injected into the deve1opment of a training plan for such sporting disciplines must therefore be related to the specificity of each of the movement patterns involved.

An optimal training plan should be developed with some general exercises to improve muscle strength and some specific exercises to improve muscle power and speed. The mechanical basis of strength training is thus very simple: overload the biological system in order to determine specific adaptations. Since the environment of our biological sys- tem is characterised by the fact that we are all subject to the action of gravity which pro- vides the major portion of the mechanical stimulus responsible for muscle structure in everyday life and training, we need to alter the biological system by increasing the gravitational load in order to enhance strength. It should be remembered that specific programmes for strength and explosive power training employ exercises performed with fast, abrupt variations of gravitational acceleration (Bosco, 1992).

To give an example, the simulation of hypergravity (wearing vests with extra Ioads) has been utilised for improving explosive muscle power (Bosco et al. 1984; Bosco 1985). The overload or simulation of hyper- gravity are not the only means for changing the gravitational conditions. In fact, mechanical vibrations applied to the body can produce changes in the gravitational conditions and determine specific responses. The studies conducted from our group were aimed to investigate the effects of vibrations applied to the whole body or to part of it in terms of hormonal responses, explosive power, neuromuscular performance and strength. This article aims to present the latest findings on vibrations and some considerations for their use in the athletic setting.

The effects of vibrations on human performance

The first study carried out by our group was conducted to study the effects of whole body vibrations on the mechanical power of the lower limbs. For this aim, fourteen active subjects involved in team sports training voluntarily participated in the experiment. After being randomly assigned to either an experimental or a control group, they were tested on an Ergojump (MAGICA, Rome, Italy) for assessing vertical jumping ability. The treatment group underwent whole body vibrations at a frequency of 26 Hz (displacement = 10mm, acceleration = 54 mos-1) for 5 repetitions lasting 90 sec. each and separated by an interval of 40 sec.. This procedure was continued for 10 days, the duration of vibration series being extended by 5 sec. every consecutive day up to a total of 2 min. per set.

At the end of the 10-day period the subjects were re-tested. The results showed remarkable and significant (p<.05) enhancement of the height and mechanical power of the best jump during the 5 sec. continuous jumping test (5sCJ) (Bosco-Vittori test, see Bosco, 1992b). The average height of rise of the centre of gravity in the 5sCJ was also significantly improved (p<.01). As expected, no changes were observed in the control group (see Figures 1 and 2).

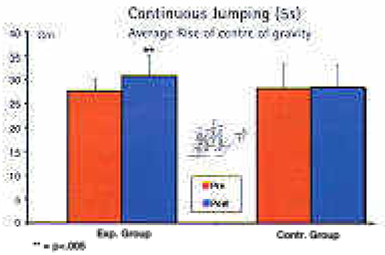

Figure1 Average rise of centre of gravity during 5sCJ measured before and after 10 days of whole body vibrations treatment.

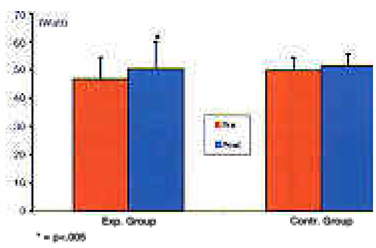

Figure 2 Mechanical power of the best jump performed during 5sCJ measured before and after 10 days of whole body vibrations treatment

Considering the fact that the 5sCJ test is a testing protocol characterised by a stretch-shortening cycle (SSC), a small angular displacement and fast stretching speed, it can be considered that since leg extensors muscles experience fast stretching this may elicit a concurrent gamma-dynamic fusimotor input that would enhance primary afferent discharge. Taking this into account, it was argued that the biological mechanism pro- duced by vibrations was similar to the effect produced by explosive power training (Bosco etal.1998).

After the latter experiment, another study was conducted to observe the behaviour of human skeletal muscle following one session of 10 minutes application of whole body vibration treatment. In this case the subjects were six female elite volleyball players. They were tested before and after the treatment while performing a maximal dynamic leg press exercise with increasing loads (70, 90, 110 and 130 kg respectively) with a sensor machine (Muscle Lab. Ergotest, Langesund Norway) able to calculate average velocity, average power and average force corresponding to load displacements (for details see Bosco et al. 1995).

After the control test, one leg was randomly assigned to the experimental treatment consisting of vibrations and the other was considered as a control.

Results showed an alteration of the V-F and P-F relationships after VT lasting only 10 min (see Figure 3; Bosco et al. 1999a). In fact, both relationships were shifted to the right indicating a clear enhancement of performance which was previously observed only after several weeks of resistance training (i.e. Coyle et al. 1981; Hakkinen and Komi, 1985).

The above mentioned findings are all related to the effectiveness of vibrations in enhancing performance in the lower limb muscles.

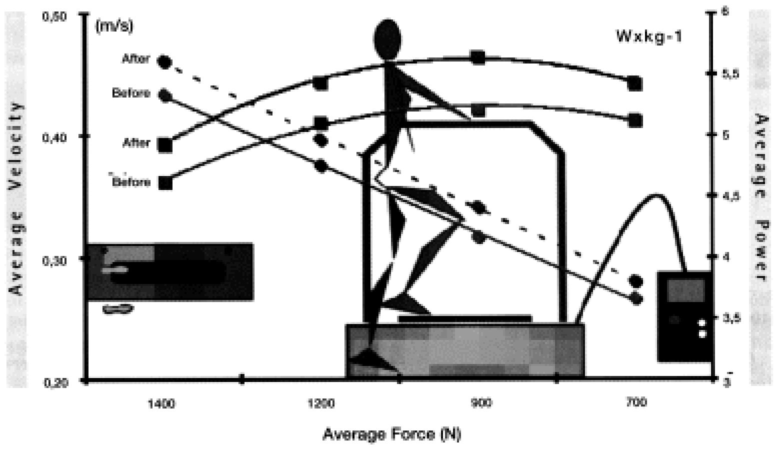

FIGURE 3 The effects of vibrations on force-velocity and power-velocity relationships in volleyball players.

Vibrations applied to the upper limbs have also been found to produce an enhancement of neuromuscular performance. In fact, in a study conducted on 12 national level boxers, vibrations applied to the arm determined an increase in average mechanical power (See Figure 4) during a maximal arm curl with an extra load of 5% body mass. In this study, in which the treatment consisted of five repe- titions of vibrations lasting 1 min. each with 1 min. rest interval at a frequency of 30 Hz, EMGrms was collected during the arm curl test and during the treatments. The results showed a significant decrease in the EMGjPower ratio following the treatment, suggesting an improvement in the neural efficiency of the neuromuscular system (see Figure 5). Moreover, the EMGrms recorded during each set of the vibration treatment reached values higher than 200% of the baseline values.

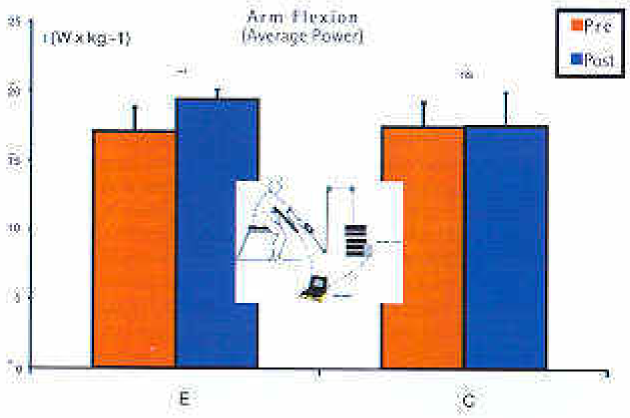

FIGURE 4

Mechanical power measured during arm curl in elite boxers before and after the vibrations treatment

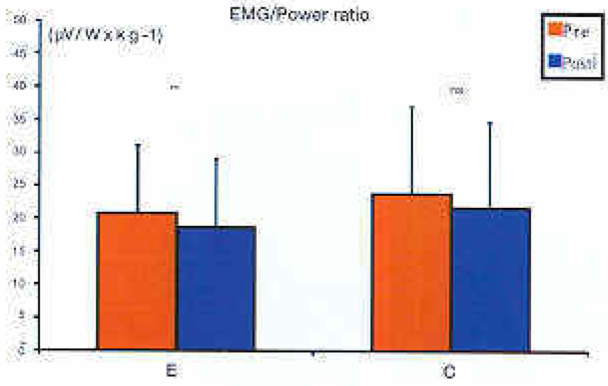

FIGURE 5

EMG/P ratio following vibrations treatment in elite boxers performing arm curls

The hormonal responses to vibrations were studied in handball players who underwent 7 repetitions of 1 min. each of vibrations and a test on vertical jumping performance. In this study, six players of the Italian national team were tested before and after the whole body vibration treatment of 7 min. on aspects such as blood concentration of Testosterone (1), Cortisol (C), growth hormone (GH) and vertical jump performances. The results showed significant decreases in vertical jumping ability and T and C. suggesting that the 7 min. of treatment represented a stressful load leading to an acute under-performance response (Bosco et al. 1999b). These results were similar to the response gained by a single session of heavy resistance exercises. In this context it should be noted that some authors have shown an increase in serum T (i.e. Weiss et al. 1983) after heavy strength training exercises, while others have demonstrated relative strength loss and hormonal decrease during one acute session of exercises (i.e. Hakkinen and Pakarinen, 1985; Bosco et al., in-press).

For further clarification of the hormonal response, another study was carried out with the aim of evaluating a different protocol of administration of the vibration treatment. In this study, fourteen male subjects were ex- posed to whole body vibrations of 10 repetitions of 60 sec. with 60 sec. rest between each vibration (after 5 reps there was a rest interval of 6 min.). The measurements carried out before and after the treatment were: vertical jumping ability, maximal dynamic leg press with an extra Ioad of 1600/0 of the subjects' body mass, EMGrms from vastus medialis and lateralis recorded during leg-press measurement and blood samples for determining T, C, and GH concentration in the blood. The results showed an enhancement t>f jumping performance (+40/0, p<.001), a marked and significant enhancement of mechanical power output when performing the leg press, a reduction of EMG activity connected to an increase in neuro- muscular efficiency through a decrease in EMG/P ratio. Significant increases in serum T (+7%, p<.03) and GH (+4600/0, p<.014) were also found, together with a significant reduction in C concentration.

All the above-mentioned findings suggest that vibrations are without any doubt a useful means for enhancing neuromuscular performance and triggering specific hormonal responses.

However, it is important to under- line that these responses are very similar to the ones reported in the literature for strength training. It can therefore be stressed that vibrations represent a valid alternative to strength training or can be implemented in a strength training programme for further improvement of human performance.

The scientific basis of vibrations

The facilitation of the excitability of the spinal reflex has been elicited through vibration of the quadriceps muscle (Burke et al., 1996). Lebedev and Peliakov (1991) have aIso suggested the possibility that vibrations may elicit excitatory inflow through muscle spin dle-motoneurons connections in the overall motoneuron inflow.

It has been demonstrated that vibration drives alpha-motoneurons via the la loop producing force without decreasing motor drive (Rothmuller and Cafarelli, 1995).

Although it has been suggested that the vibration reflex, like the tendon jerk reflex, operates predominantly or exclusively on alpha motoneurons and does not utilise the same cortically originating efferent path- ways as are used when performing voluntary contractions (Burke et al. 1976). it cannot be excluded that vibration treatments can also affect voluntary movements. These suggestions are supported by the present findings.

In fact the EMG recorded in the biceps brachii of the experimental group in the study conducted on boxers showed a significant enhancement (P<O.OOl) of the neural activity during the treatment period, as compared to normal conditions (Bosco et al. 1999a).

It has been shown that the vibration-induced activation of muscle spindle receptors not only affects the muscle to which vibration is applied, but also affects the neighbouring muscles (Kasai et al. 1992). A mechanical vibration (10-200 Hz), applied to the muscle belly or tendon can elicit a reflex contraction (Hagbarth and Eklund, 1965). This response has been named "tonic vibration reflex" (1VR). It is not known whether it can be elicited by low vibration treatment (30 Hz), even if it has been suggested to occur during whole body vibration at frequencies ranging from 1 to 30Hz (Seidel , 1988).

The improvement of the muscle performance after a short period of vibration training has been quoted (Bosco et al. 1998) to be similar to what occurs after several weeks of heavy resistance training (e.g. Coyle et al. 1981, Hakkinen and Komi 1985). In fact the improvement of the muscle functions after resistance training has been attributed to the enhancement of the neuromuscular behaviour caused by the increasing activity of the higher motor centre (Milner -Brownet al., 1975). The improvement of muscle performances induced by VT suggests that a neural adaptation has occurred in response to the vibration treatments. In this context, the duration of the stimulus seems to be both relevant and important. The adaptive response of human skeletal muscle to simulated hypergravity conditions (1.1 g). applied for only three weeks, caused a considerable improvement in the leg extensor muscle behaviour (Bosco. 1985). Thus it is likely that both neural adaptation and the length of the stimulus seem to play an important role in the improvement of muscle performances (e.g. Bosco, 1985).

During the VT utilised for the research conducted on the boxers, the elbow flexors were stimulated for a total length of time of 300 seconds. The duration of the treatment was similar to that required to perform an elbow flexion for 600 repetitions with a load similar to 50/0 of the subject's body mass. Such an amount of repetitions would generally otherwise be distributed over 3 sessions a week with 50 repetitions per time, taking one month to complete. The large initial increases noted in muscle strength observed during the earlier weeks of intense strength training can be explained through increases in maximal neural activation (e.g. Moritani and De Vries , 1979).

To explain how the increased neural output may occur is not as simple as how to explain the intrinsic mechanism of neural adaptation. Furthermore, a net excitation of the prime mover motoneurons could result from increased excitatory input, reduced inhibitory input or both (e.g. Sale, 1988). After the VT period the EMG activity was found to be rather lower or to be the same as com- pared to the pre-treatment conditions even if, during the vibration, period an increment of neural input to the muscle occurred. In this respect the decrease in the ratio between EMG and mechanical power (EMG/P) demonstrated that VT induced an improve- ment of the neuromuscular efficiency of the muscles involved in the vibration treatment.

Vertical jumping ability has been shown to increase following vibration treatment (Bosco et al. 1998; Bosco et al. In-press). These improvements have been attributed to an enhancement of neural activity in the leg extensor muscles, together with an enhancement of the proprioceptors' feedback. During vibrations, the length of skeletal muscles changes slightly. The facilitation of the excitability of spinal reflexes has been shown to be elicited by vibrations applied to the quadriceps muscle (Burke et al. 1996).

Once again, the influence of vibrations on the neural drive of the la loop can playa crucial part in enhancing jumping performance following vibration treatments. Even if the adaptive responses of neuromuscular performance as measured by vertical jump tests cannot be fully explained, it is important to consider that the effectiveness of the stimulus can have both relevance and importance.

The adaptive response of human skeletal muscle to simulated hypergravity conditions (1.1 g), applied for only three weeks, caused a drastic enhancement of the neuromuscular functions of the leg extensor muscles (Bosco. 1985).

The regular use of centrifugal force (2 g) for 3 months has initiated conversion of muscle fibre type (Martin and Romond, 1975). In the experiments conducted, the total length of the WBV application period was not very long (from 7 minutes to 100 minutes), but the disturbance to the gravitational field was quite consistent (5.4 g). An equivalent length and intensity of training stimulus (100 minutes) can only be reached by performing 200 drop jumps from 60 cm, twice a week for 12 months. In fact, the time spent for each drop jump is less than 200 ms, and the acceleration developed can barely reach 3.0 g (Bosco. 1992). This means stimulating the muscles for 2 min per week for a total amount in one year of 108 minutes. In a few words, vibrations can stimulate the biological system of athletes in the same way as strength training or explosive training and this stimulation can be applied in a much shorter period of time as compared to the time needed to perform traditional training sessions. It opens a new window in sports science and gives coaches and scientists new possibilities for studying and enhancing human performance.

Conclusion

The use of vibrations in an athletic setting offers new possibilities to coaching science. Resistance training effectiveness has been demonstrated due to the possibility of enhancing neuromuscular performance, power output. strength and hormonal profile. However. the time needed for these adaptations to occur is relatively long as compared to the possibilities offered by vibration treatments. It should be recognised however, that vibrations need to be viewed not as a substitute tool of resistance exercise. but as a valid additional means to be implemented in a training routine in association with all the other traditional methodologies nowadays utilised. New studies need to be conducted to analyse chronic responses. different treatment protocols and the effects of the association of vibrations with conventional training means for improving the knowledge in this interesting and exciting tool of sports science.

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