Short communication

ADAPTIVE RESPONSES OF HUMAN SKELETAL MUSCLE TO VIBRATION EXPOSURE.

C. Bosco [1,2,3], R. Colli [5], E. Introini, M. Cardinale [4], M. Iacovelli [6], J. Tihanyi [3], S.P. von Duvillard [7], A. Viru [8]

[1] University of Rome -Tor Vergata, Fondazione 'Don Gnocchi", Rome, Italy
[2] Department of Biology of Physical Activity, University of Jyvaskyla, Finland
[3] Department of Biomechanics, Hungarian University of Physical Education, Budapest, Hungary
[4] Research and Study Center, Italian Handball Federation
[5] Research and Study Center Italian Cycling Federation
[6] University of Rome - La Sapienza,II Chair of Human Physiology, Italy
[7] Department of HPER, University of North Dakota, Grant Forks, USA
[8] Institute of Exercise Biology, University of Tartu, Estonia

Key 'Words: Vibration, muscle mechanics, force/velocity

Correspondence

Carmelo Bosco Ph.D.
C /o Societa Stampa Sportiva
Via G.Guinizzelli,56
00 152 Roma,Italy
Phone+39335283024;+393482680265
Fax : + 39 6 5806526
E-mail : C.Bosco@

ABSTRACT

The study was performed in order to test the possibility wheather a single whole body vibration (WBV) session will produce human skeletal muscle response. In 6 female volleyball players movement velocity, muscle force and power were recorded when they performed maximal leg press exercises with extra load of 70,90,110 and 130 kg. The testing took place before and after a 10-min WBV exposure. During WBV subjects were in the standing position with the toes of one leg on the vibration platform (E leg) while the other leg (C leg) was risen from the ground. WBV induced statistically (P<O.O5) significant improvement of the movement velocity, muscle force and power. In result-, the velocity-force and power-force curve were shifted to the right. C leg failed to show changes in studied mechanical variables after the WBV session. In conclusion, the acute effect of a short term WBV on neuromuscular apparatus is expressed by improved movement velocity, muscle force and power in performing leg press exercise with external loads.

INTRODUCTION

Skeletal muscle is a specialised tissue which modifies its overall function capacity in response to chronic exercise with high loads (e.g. McDonagh and Davies **1984).** Intensive prolonged strength training is known to induce a specific neuromuscular (e.g. Sale, 1988) and hormonal (e.g. Guezennec et al., 1986) adaptive responses in the human body in few months, while the changes in the morphological structure occur later (e.g. Sale,1988). However, the exact mechanism which regulate how the body adapts to the specific demands upon it, is still unknown. Even less knowledge are available in respect to fatigue, relative strength loss and hormonal changes during one acute session of exercises (e.g. Hakkinen & Pakarinen 1995, Bosco et al. 1998, in-press). It should be remind, that specific programs for strength and explosive power training are based on exercises performed with rapid and violent variation of the gravitational acceleration (Bosco,1992). In this connection it should be remind that changes of the gravitational conditions can be produced also by mechanical vibrations applied to the whole body. Whole body vibration applied for ten minutes during 10 days treatment period have induced an enhancement of explosive power performances in physical active subjects (Bosco et al. 1998, submitted for publication). A question arises from these results: how human skeletal muscle response to a single session of 10 minutes application of whole body vibration in well trained athletes? The present study was performed in order to answer of the question.

METHODS

Six female volleyball players of national level (age : **19.5 ± 2.1 years** ; weight : 65.1 ± 3.7 kg ; height : 174.9 ± 3.2) voluntarily participated to the study. They were physically active and were engaged in team sport training program 5 times a week . Each subject was instructed on the protocol and signed an informed consent to participate in the experiment. Subjects with previous history of fractures or bone injuries were excluded from the study, The study design was approved by the ethical committee of the Italian Society of Sport Science.

Procedures: Ten minutes warm up was performed:5 minutes of bicycling at 25 km-h-' on a cycle ergometer (Newform s.p.a., Ascoli Piceno, Italy) and five minutes of static stretching for the quadriceps and triceps surae muscles. After the warm up, all the subjects, well accustomed with the exercises, performed maximal dynamic leg press exercises on a slide machine (Newform s.p. a., Ascoli Piceno, Italy) with extra loads of 70,90,110 and 130 kg . **One** leg per time was used for each load. The best trail of three measurements for each load was **used for** statistical **analysis. During** the test, the vertical displacements of the loads were monitored with simple mechanics and sensor arrangement (Ergopower ®, Ergotest Technology A. S ., Langensund, Norway). The loads were mechanically linked to an encoder interfaced to an electronic microprocessor (Muscle Lab, Pat. No. 124 1671). When the loads were moved by the subjects a signal was transmitted by the sensor every 3mm of displacement. Thus it was possible to calculate average velocity (AV), acceleration, average force (AF), and average power (AP), corresponding to the load displacements (for details see Bosco et al., **1995).**

Reproducibility of the measurements. . The dynamic exercises reproducibility testing gave a test-retest correlation r = 0.45 for the average power (P) (Bosco et al., 1995).

Treatment Procedures : Subjects were exposed to vertical sinusoidal whole body vibration (WBV) using the device called GALILEO 2000 (Novotec, Pforzheim, Germany). The frequency of the vibrations used in this study was set at 26 Hz (displacement = 10mm ; acceleration = 27 $m \cdot s^{-2}$). The subjects were exposed ten times for a duration of 60s with 60s of rest between the treatment each.

Type of treatment employed: The application was performed in the standing position with the toes of one leg on the vibration platform, the knee angle was pre-set at 100° flexion, while the other was risen from the ground. During all the treatments the subjects were asked to wear gymnastic-type shoes to avoid bruises. The leg which was exposed to vibration was assigned to E group , while the other not exposed was assigned to C group. Thus , in each subject one leg was exposed to vibration (E) and the other was considered as control (C). The leg randomly assigned to each E or C groups demonstrated similar mechanical behaviour before the vibration (VT) exposure (Table 1). Testing procedures were administered at the beginning (Pre) and immediately after (Post) the VT period.

Statistical methods : Conventional statistical methods used included mean, standard deviation , paired and unpaired Student’s t-test. The, level of significance was set at $P < .05$.

RESULTS

Before the VT period, no significant differences was found in the mechanical behaviour between E and C legs in parameters studied (AF,AV, and AP) for all loads used (70, 90,110 and 130 kg) (Table 1) . After the VT period the legs affected by vibration (E) showed statistically significant improvement (Pre vs Post) of the AF, AV and AP developed with all loads used ($P < 0.05 - 0.005$) (Table 1). In result, the velocity-force (V-F) and the power-force (P-F) curves (Fig. 1), established by the variables shown in Table 1, were shifted to the right after the VT period. Only the AF developed with 70 kg remained unchanged after the VT period . In contrast , the mechanical behaviour of the C legs, demonstrated no changes in mechanical variables studied by the Pre - Post test analysis (Table 1). Only the AV developed with 130 kg showed statistically significant improvement (near 3 %) in the Post evaluation test ($P< 0.05$).

DISCUSSION

As expected the Pre vs Post test analysis performed for the C legs did not show any modification in the mechanical properties studied. This is not a surprising finding, since, in half -squat exercises performed with extra load (100 % of subject's body mass) no change has been observed in twelve female and male throwers during same day (Bosco et al., 1995). However , the AV developed with 130 kg showed statistically significant improvement in the Post evaluation test of C leg ($P< 0.05$). Reasonable explanation for this improvement cannot be easily found, considering that the athletes of the present experiments were well accustomed with this type of exercises and therefore any learning effect of the movement executed could be excluded. The mechanical behaviour of the E legs demonstrated a dramatic alterations in the V-F and P-F relationships after VT lasting only ten minutes. Changes and shifting to the right of force-velocity (F-V) relationship have been observed after several weeks of heavy resistance training (e.g. Coyle et al., 1981: Hakkinen & Komi, 1985). The improvement of the of the F-V relationship has been attributed to the enhancement of the neuromuscular behaviour caused by the increasing activity of the higher motor center (Milner-Brown et al., 1975). Thus , it is likely that also the VT have caused a dramatic enhancement of the neural traffic regulating the neuromuscular behaviour (Bosco et al., 1998, submitted for publication) .

During vibration of the body skeletal muscles undergo small changes in muscle length. Facilitation of the excitability of spinal reflex has been elicited through vibration to quadriceps muscle (Burke et al., 1996). Lebedev and Peliakov (1991) pointed on the possibility that vibration may elicit excitatory flow through short spindle - motoneurons connections. Burke et al. (1976), suggested that vibration reflex operates predominantly or exclusively on alpha motoneurons and does not utilise the same cortically originating efferent pathways as are in the performance of voluntary contractions, However, a facilitation of voluntary movement cannot be excluded. In the present study, any neurogenic potentiation has not been demonstrated since no EMG recordings were performed. Nevertheless, enhancement of the mechanical behaviour strongly suggests that a neurogenic adaptation have occurred in response to the vibration treatments. Therefore, even if the intrinsic mechanism contributed, the adaptive response of neuromuscular functions to VT could not be explained by it. The duration of the stimulus seems to have relevant importance_ Adaptive response of human skeletal muscle to simulated hypergravity conditions (1. 1 g), applied for three weeks, caused a drastic enhancement of the neuromuscular functions of the leg extensor muscles shifting the F-V relationship to the right (Bosco, 1985). In the present experiment, even if the total length of the VT application period was only 10 minutes, the perturbation of the gravitational field was rather consistent (2.7 g). An equivalent length and intensity of training stimulus can be reached only by performing 150 times leg press or half squat exercises with extra loads of 3 body mass twice a week for 5 weeks (Bosco,l992).

References

Bosco C. (1985). Adaptive responses of human skeletal muscle to simulated hypergravity condition. *Acta Physiol Scand* **124: 507-5 13**.

Bosco C. (1992). The effects of extra-load permanent wearing on morphological and functional characteristics of leg extensor muscles, Published Doctoral Thesis, Université Jean-Monnet de Saint Etienne,France.

Bosco C., Belli A., Astrua M., Tihanyi J., Pozzo R., Kellis S., Tsarpela **O,** Foti C., Manno R, & Tranquilli C. (1995). Dynamometer for evaluation of dynamic muscle work. *Eur J Appl Physiol* **70 :379-386.**

Bosco C., Colli R., Bonomi R., von Duvillard S.P., & Viru A, Monitoring strength training. Neuromuscular and hormonal profile. *Med Sci Spor Exer 1998 (in press).*

Bosco C., Cardinale M., Colli R., Tihanyi J., von Duvillard S.P., & Viru A. The influence of whole body vibration on the mechanical behaviour of skeletal muscle. Biol Sport, 1998 (submitted for publication).

Burke J.R., Rymer W.Z. & Walsh H.V. (1976). Relative strength of synaptic inputs from short latency pathways to motor units of defined type in cat medial gastrocnemious. *Neurophysiology* **39**: 447-458.

Burke J.R., Schutten **M.C.,** Koceja D.M. & Kamen G. (1996). Age-dependent effects of muscle vibration and the Jendrassik maneuver on the patellar tendon reflex response. ***Arch*** *Phys Med Rehabil* 77(6): **600-604.**

Coyle E., Feirin C., Rotkis T., Cote R., Roby F., Lee W., & Wilmore J. (198 **1).** Specificity of power improvements through slow and fast isokinetic training. *J Appl Physiol* 51: 1437-1442.

Guezennec Y., **Leger** L., Lhoste F., Aymonod M. & Pesquies PC. (1986) **Hormone** and metabolic response to weight-liftig training sessions. lnt J Sport Med 7 : 100-105.

Hakkinen K., & Komi P.V. (1985). Effect of explosive type strength training on electromyographic and force production characteristics of leg extensors muscles during concentric and various stretch-shortening cycle exercises. *Scand J Sports Sci* **7 (2): 65-76.**

Hakkinen H., & Pakarinen A. **(1995).** Acute hormonal responses to heavy resistance exercise in men and women at different ages. *Int J Sports Med 16* : 507-513.

Lebedev M.A., & Peliakov A.V. (1991). Analysis of the interference electromyogram of human soleus muscle after exposure to vibration. *Neirofiziologia* 23 (1): 57-65 (article in Russian).

McDonagh M.J.N., & Davies C.T.M. (1984). Adaptative response of mammalian skeletal muscle to exercise with high loads. *Eur J Appl Physiol* **52**: 139-l 55.

Milner-Brown H.S., Stein R.B., & Lee R.G. (1975). Synchronization of human motor units: possible roles of exercise and supraspinal reflexes. Elettorenceph Clin Neurophys 38: 245-254.

Sale D. G. (1988). Neural adaptation to resistance training Med Sci Sports Exerc 20 : 13 S-145.

Table 1. Mean values (x) ± standard deviation (SD) of the Average Power (AP), Average Velocity (AV) and Average Force (AF) measured during leg press performances executed with progressive extra-loads, before and immediately after WBV treatment, in the Experimental leg and in the Control leg.

EXPERIMENTAL LEG

Load (kg)		AP (W)		AV (m/s)		AF (m/s)	
		Before	After	Before	After	Before	After
70	X	**319**	**340 ****	**0.434**	**0.462 ***	**735**	**737**
	SD	**21**	**11**	**0.025**	**0.015**	**6**	**5**
90	X	**352**	**375 *****	**0,374**	**0.398 *****	**936**	**941 ***
	SD	**11**	**4**	**0.011**	**0,003**	**8**	**9**
110	X	**359**	**389 *****	**0.317**	**0.342 *****	**1134**	**1138 ***
	SD	**25**	**21**	**0.018**	**0.015**	**14**	**15**
139	X	**354**	**373 *****	**0.267**	**0.281 *****	**1324**	**1327 ***
	SD	**42**	**42**	**0.028**	**0.027**	**20**	**19**

CONTROL LEG

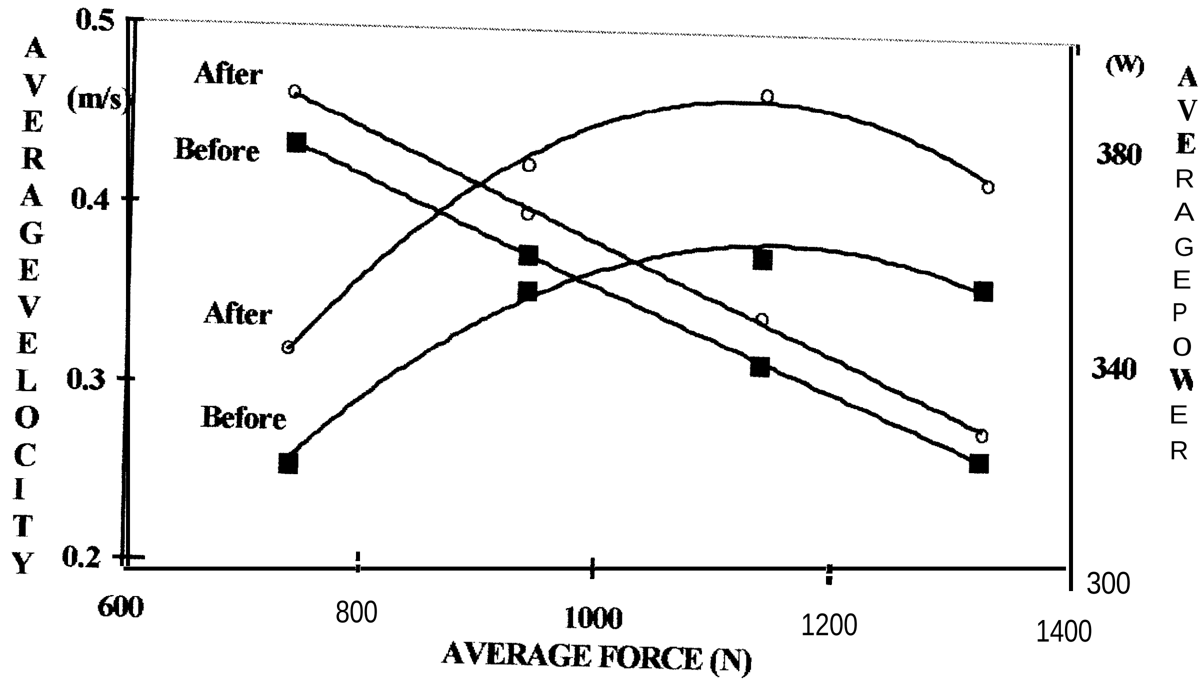
Load (kg)		AP (W)		AV (m/s)		AF (m/s)	
		Before	After	Before	After	Before	After
70	X	**318**	**321**	**0.43 1**	**0.436**	**737**	**736**
	SD	**25**	**8**	**0.032**	**0.010**	**5**	**5**
90	X	**348**	**363**	**0.371**	**0.387**	**937**	**937**
	SD	**18**	**23**	**0.016**	**0.022**	**11**	**12**
110	X	**372**	**373**	**0.327**	**0.328**	**1136**	**1137**
	SD	**23**	**19**	**0.019**	**0.013**	**5**	**15**
139	X	**360**	**372**	**0.272**	**0.279***	**1324**	**1328**
	SD	**44**	**37**	**0.03**	**0.025**	**14**	**17**

Significant difference before and after treatment:

*	P<0. 05
**	P<0.01
***	P<0.00 1

LEGENDS

Figure 1. Average velocity (AV), and average power (AP) developed during leg press exercise performed with various loads (70,90, 110, 130 kg) are shown according to the average force (AF) before (filled symbols) and after (open symbols) VT period. The statistical differences for AF, AV, and AP values together with different loads used are showed in Table 1,



AVERAGE VELOCITY (m/s)
0.5
0.4
0.3
0.2
After
Before
After
Before
(W)
AVERAGE POWER
380
340
300
600
800
1000
1200
1400
AVERAGE FORCE (N)