THE EFFECTS OF WHOLE-BODY VIBRATION ON EMG OF LEG MUSCLES WHICH ARE DIFFERENT FATIGUE RESISTANT DURING STATIC CONTRACTIONS

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The purpose of the present study is to determine the effects of static whole body vibration (WBV) stimuli at low (2 mm) and high (4 mm) amplitudes and various frequencies (30-35-40 Hz) on the neuromuscular responses of leg muscles which are different fatigue resistant. The fatigue protocol used for the determination of the fatigue index (FI).The study population was divided into two groups according to the values obtained by the FI (Group I: Less Fatigue Resistant (LFR), n=11; Group II: More Fatigue Resistance (MRF), n=11). Study results showed that LFR group that experienced a significantly higher percentage increase in the EMG activation values during higher frequencies (40 Hz) and amplitudes (4mm) (p<0,05). The highest level of muscular activation of MRF groups' was observed at 4 mm amplitude and 35 Hz frequency and thereafter tended to decrease (p<0,05).

KEYWORDS: fatigue, resistant, optimal, sport, muscle activation, electromyography

INTRODUCTION: WBV exercises have increasingly become popular and aroused much interest, particularly among elite athletes, who extensively perform WBV exercises to increase muscular performance (Bosco et al., 1999; Cochrane &Stannard, 2005). The basic process underlying this is the development of involuntary reflex contractions through tonic vibration reflex (TVR) (Hagbarth&Eklund, 1966; Burke et al., 1976). Frequency and/or amplitude shifts generated by the WBV platform results in changes in the length of the muscles.

METHODS: Subjects were enrolled based on an isokinetic fatigue protocol and divided into two groups according to their F.I. (%50 or less MRF group, n=11): 21.72±2.05 years, 176±5.02cm, 71.94±6.03 kg, BMI 23.20 ± 1.99 kg/m2; %50 or over LFRgroup, n=11): 21.63±1.20 year, 180±6.06 cm, 75.94±6.69 kg, BMI 23.41±1,30 kg/m^2). All subjects gave written informed consent to participate in the experiment. The study was approved by the local ethics committee.
Isokinetic Data Acquisition and Analyses: During the tests, the subjects were requested to perform 50 reciprocal maximal concentric contractions using the dominant knee, at 180^0 sec^{-1} angular speed. Knee flexor and extensor muscle fatigue was determined by two methods of calculation: the fatigue index and the slope.
The fatigue index was determined by the following formula to:
Percent decrease = 100-[(work last 3 repetitions/work first 3 repetitions) X100]
The slope was determined via linear regression analysis by plotting the windowed work values for each repetition across the 50 contractions for each subject.
EMG Data Acquisition-Analyses and MVIC Measurement:Superficial EMG signals were recorded from the rectus femoris (RF), biceps femoris (BF), vastuslateralis (VL), and vastusmedialis (VM) muscles of the dominant leg. The recordings were obtained using a 16-channel Delsys Wireless Trigno Electromyography (EMG) system. The gain, frequency band, maximum intraelectrode impedance, and common noise removal ratio (CNRR) of the EMG amplifier were 1000, 20–500 Hz, 6 kOhm, and 95 dB, respectively. EMG signal sampling rate and bit rate of the analogue-digital converter were set to 2000 Hz and 16 bits, respectively. MVIC tests were undertaken with the subject fastened to the Cybex isokinetic dynamometer (Humac Norm Testing and Rehabilitation System, USA). The maximal trial used for further analyses. MVIC of RF, VL, VM was assessed by knee extension when in a sitting position

with the knee at 65° (0° full extension) while MVIC of the hamstrings (long head of BF) was assessed in a prone position with the knee at 30°.All EMG signals were normalized to the maximum EMG signals recorded during maximal voluntary contractions and presented as % MVIC. EMG data processing was performed using MatLab (MathWorks R2012a). The EMG signals were band-pass filtered (20–450 Hz) and smoothed using Root-Mean-Square and a 500 ms moving-window function. Motion artifact components on recorded EMG signals were filtered out using an infinite impulse response notch filter (3 dB Band=1.5 Hz) centered on the applied vibration stimulus frequency and its harmonics. Notch filters were applied for all recordings, except EMGs of the resting periods.

Vibration Data Acquisition: Before the experimental protocol, a familiarization session was performed with all subjects to acclimate them to the WBV sensation. The subjects were asked to perform static half squatting position with a knee flexion angle ~120^0 (this was measured by a goniometer) with their arms flexed ~90^0. At the beginning of each measurement, baseline activity (without vibration) was performed. After, baseline measurement was lasted 30sn, participants were randomly exposed to 6 different test conditions on a vibration platform (Compex WINPLATE, Galileo 2000, Novotec Medical GmBH, and Germany). Test condition lasted 30sn, with 5min of rest between each condition and 10min of rest before 4mm amplitude condition to prevent fatigue.

Statistical Analyses: Before statistical analyses, all the EMG measures were normally distributed, as determined by the Shapiro Wilk test. The dependent variables in all statistical tests were iEMG values measured from the muscles RF, VM, VL and BF. The independent variables were group (MRF and LFR), vibration frequency (30-35-40Hz) and vibration amplitude (2mm and 4mm). In order to detect interaction effects between the independent variables, a repeated measures ANOVA [group (2) x frequency (3) x amplitude (2)]. A Bonferroni post hoc test was in all pairwise comparisons when a significant results was found. Vibration data were analysed using PASW/SPSS Statistics 18.0 (SPSS Inc, Chicago, IL) and significant level was set at P< 0.05.

RESULTS: Increases in VM, VL, RF and BF muscle activity with WBV compared with no WBV during a static-squat are presented **Figure 1(a-d)**.

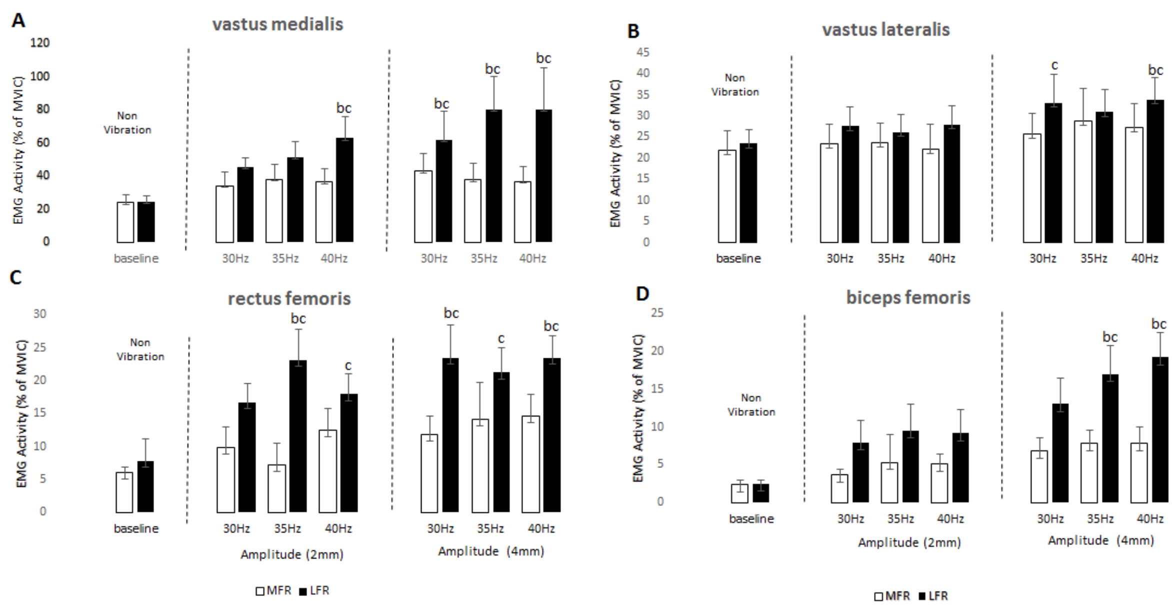

Figure 1. Increases in VM, VL, RF and BF muscle EMGrmsactivity with WBV compared with no WBV during a static squat. Black and open bars respectively show LFR and MRF groups EMG activity in different frequency and amplitude values. Values are mean ± SE. Significantly greater than baseline

($p<0.05$). Character (a,b,c) indicate significant difference in activity levels between frequencies during either high or low amplitude vibration.

- MRF Group Baseline-MRF Group 30, 35Hz, 40Hz (2mm) / 30, 35Hz, 40Hz (4mm)**: a** ($p<0.05$).
- LFR Group Baseline-LFR Group 30, 35Hz, 40Hz (2mm) /30, 35Hz, 40Hz (4mm):**b** ($p<0.05$).
- MRF Group Baseline -LFR Group 30, 35Hz, 40Hz (2mm) / 30, 35Hz, 40Hz (4mm): **c** ($p<0.05$).

DISCUSSION: Little is still known about the most optimal dose-response relationship between the vibration stimulus and its effect on muscle electromyographic activity. Since the other studies reported mostly the influence of the only vibration frequency or amplitude parameter, this study concentrates on effects of whole-body vibration on EMG of leg muscles which are different fatigue resistant during static contractions.This is the first study that determine the effects of static whole body vibration (WBV) stimuli on the LFR and MFR group leg muscles electromyographic activity. The frequencies applied were 30 Hz, 35 Hz, 40 Hz, while the amplitudes were 2 mm and 4 mm.
The findings of the present study demonstrate that the LFR group experienced a significantly higher rate of knee extensor and knee flexor muscle fatigue, than the MRF group ($p<0.001$). The results showed that LFR and MRF groups muscle activity (EMGrms) increased, although not always statistically significant, at all frequencies compared with the non-vibrating baseline measurement. Surface EMG analyses in different studies demonstrate a significant increase in muscular activity; some study reports that the EMG increase is frequency dependent (Bosco et al., 1999; Cardinale& Lim, 2003; Roelants et al., 2006). Matthews (1966) and Krol et al. (2011) which suggest that the level of muscle response to mechanical vibration depends on the applied frequency and the higher frequencies lead to greater muscle activity. In another study, Pollock et al. (2010) examined the effects of frequency and amplitude on the activity and acceleration value of six leg muscles during WBV. They observed that the muscular activation values were greater, although not always statistically significant, at high amplitudes and all frequencies, and except for the gluteus maximus and biceps femoris muscles, the muscular activation linearly increases by increasing the frequency.The other finding in this study, muscle activity (EMGrms) more increased significantly during WBV at all frequency (30Hz, 35Hz and 40Hz) in “LFR group” than the “MRF group”. The magnitude of this increase in muscle activity caused by WBV (vibration effect) was different among LFR and MRF group. When exposed to vibration, the highest electromyographic activity in LFR group was recorded when the 40 Hz frequency. However, decrease the leg muscles activation of MRF group by increasing frequency of the whole body vibration. As a result of these findings, it is of importance to emphasize that the static whole body vibration provided positive results to distinguish MRF and LFR muscle groups from each other.
Vibration amplitude are important variables that affect the muscle activity during vibration stimuli (Martin and Park, 1997, 23). The results of the present study show that increase the activation of MRF and LFR leg muscles by increasing amplitude of the whole body vibration, and represent the hypotheses of the present study.

CONCLUSION: Vibration training is a part of athletes training, rehabilitation, and activities of the fitness centres. One of the factors ensuring effective vibration training is a set of optimal vibration parameters. In conclusion, the present study indicated that the magnitude of the EMG muscle responses varies with the vibration frequency for both groups showed different responses. Moreover, the effect of vibration on the muscles is also dependent on group and amplitude. From a practical point of view and in relation to the frequency and amplitude of vibration, lower frequencies and higher amplitude (35 Hz, 4mm) are suitable for maximal muscular activation of the more fatigue resistant individuals, whereas both higher frequency and higher amplitude (40Hz, 4mm)elicit the highest muscular activation in the less fatigue resistant individuals. Present study was used 30, 35 and 40Hz frequencies, however LFRgroup’s muscular activation values were greater at 40Hz frequency. Therefore, future studies are needed to describe the muscular activation pattern at higher frequencies (45Hz and higher) for less fatigue resistant individuals.

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