FREQUENCY ANALYSIS OF THE TONIC VIBRATION REFLEX OF THE HAND FLEXOR MUSCLES

박희석

홍익대학교 산업공학과

The aims of this study were first to determine the influence of vibration displacement amplitude (200μm, 300μm peak-to-peak) at selected frequencies (40-200Hz) on a commonly observed but often undesired motor response elicited by local vibratory stimulation, the Tonic Vibration Reflex (TVR). Second, to determine the degree of synchronization of motor unit (MU) activity with vibratory stimuli. Vibration was applied to the distal tendons of the hand flexor muscles. Changes in root-mean-square electromyographic (EMG) activity of the finger and wrist flexor muscles were analyzed both as a function of their initial contraction level (0%, 10%, 20% of the maximal voluntary contraction: MVC) and as a function of the vibration parameters. The results indicate that the TVR increased with the initial muscle contraction up to 10% MVC; The TVR increased with vibration frequency up to 100-150 Hz and decreases beyond; A significant increase of the TVR with vibration displacement amplitude was observed only for the wrist flexor muscle; MU synchronization at vibration frequency (VF) was found more often in the low frequency range ($f \leq 100$ Hz) and tended to decrease beyond; In the high frequency range ($f \geq 120$ Hz), MU activity at subharmonic frequency was predominant; The "cut-off" frequency of the synchronization with VF was neither affected by the vibration displacement amplitude nor initial muscle contraction level. The surface EMG turned out to be a useful means to analyze MU synchronization since it is noninvasive, and it can be easily used for analysis of different muscle contraction levels, while single MU technique might have some difficulties at high muscle contraction levels. Furthermore, these results indicate that high frequency vibration ($f > 150$ Hz) tends to induce less muscle/tendon stress and MU synchronization. Such remarks are of importance for the design of hand-held vibrating tools.

INTRODUCTION

The tonic vibration reflex (TVR) is a commonly observed motor effect elicited by muscle tendon vibration. This motor response results primarily from the vibration-induced activity of the muscle spindle primary endings. Furthermore, it may contribute to muscle fatigue and/or increase the risk of cumulative trauma disorders observed after repetitive long-duration vibration exposure. It has been shown using the single motor unit (MU) recording technique that the discharge pattern of MUs of vibrating muscle is correlated with vibratory stimuli (Romaiguère *et al.* 1991), but few studies have been done using surface electromyography (Lebedev and Polyakov, 1992). The aims of this study were first, to determine the influence of vibration parameters on the TVR, and second, to determine the degree of synchronization of muscle activity with vibratory stimuli.

METHODS

Ten healthy subjects were tested in a seated position with the right arm supported by an arm-rest. The right hand gripped a vertical handle fixed to the arm-rest. Vibration of 200 μm and 300 μm peak-to-peak displacement amplitude was applied to the distal tendons of the hand flexor muscles at selected frequencies (40, 80, 100, 120, 150, and 200 Hz). The electromyographic (EMG) activity of the flexor digitorum profundus (FDP) and flexor carpi radialis (FCR) muscles was recorded using surface electrodes, low-pass filtered to prevent aliasing, and sampled at 1000 Hz. Experimental conditions were presented in a random order. Data was collected during a 15s control period immediately followed by a 45s vibration period.

Changes in the vibration-induced increase in RMS EMGs (RMS VIC = RMS EMGvib - RMS EMGref) were analyzed as a function of 1) muscle contraction level (0%, 10%, and 20% of maximal voluntary contraction, MVC) and 2) the vibration parameters. EMG frequency analysis using the power spectral density (PSD) was performed to determine MU synchronization with the vibratory stimulus. The PSD was calculated for the last 15s of the vibration period. Fifteen periodograms of 1024 msec were averaged and the Hanning window was used. The intensities of the MU activity synchronized with vibration frequency (I_{VF}) and its first-order subharmonic frequency (I_{SF}) were expressed as the percentages to the total power of the PSD ($I_{\Delta F}/I_{Total}$, where ΔF represents 10 Hz bin @ VF or SF). Analysis of variance (ANOVA) was performed on the ratios to examine the effects of vibration parameters and muscle contraction on the TVR and MU synchronization.

RESULTS

The main results indicated that muscle activity resulting from the TVR (RMS VIC) increases with initial muscle contraction (up to 10% MVC), and vibration frequency up to 100 and 150 Hz for the FCR and FDP muscles, respectively, and decreases beyond. However, a significant increase of the TVR with the vibration displacement amplitude was observed only for the FCR muscle (Park & Martin, 1993).

Narrow peaks in the PSD of the EMG indicated a synchronization of MU activity with the vibratory stimulus and/or its first harmonic frequency (Figure 1).

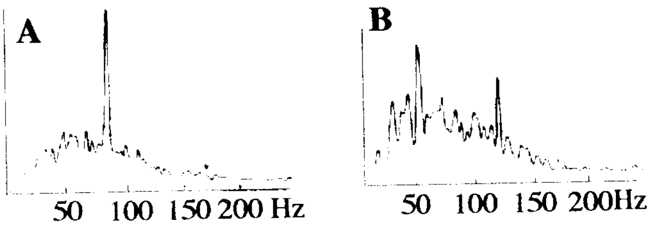

Figure 1. Power Spectral Density of the EMG signals. Narrow peaks show MU synchronization with VF (**A**: 80 Hz vibration), with VF and SF (**B**: 120 Hz vibration).

The intensities of MU activity synchronized with VF and SF were averaged across all the experimental conditions and subjects (Figure 2). Synchronization at VF was found more often in the low frequency range (F≤100 Hz) and tended to decrease beyond. In the high frequency range (F≥120 Hz), MU activity at SF was predominant. The intensity of MU synchronization at VF ≤100 Hz was larger for the FCR than the FDP muscle (Figure 2). MU activities synchronized with VF tend to decrease beyond 80-100 Hz range for both flexor muscles, while MU activity at SF increases with the stimulus frequency. The ANOVA indicated that the "cut-off" frequency of the synchronization with the VF was neither affected by the vibration displacement amplitude nor initial muscle contraction.

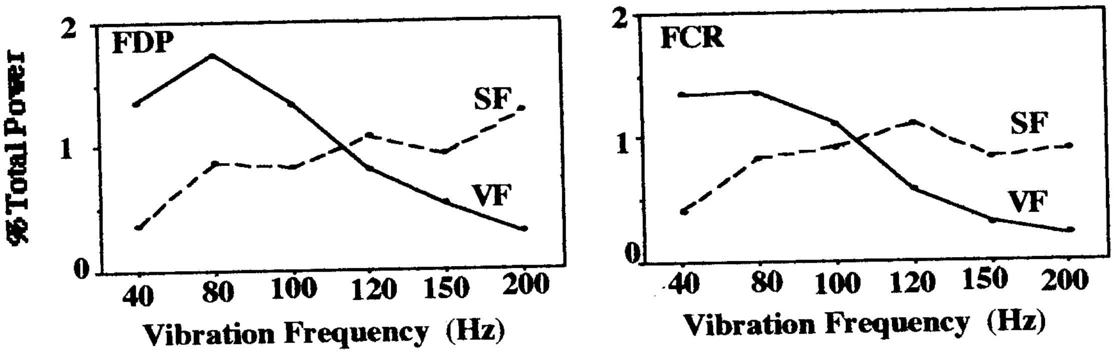

Figure 2. Percentages of the intensities of MU activity synchronized with VF and SF.

DISCUSSION

A saturation of the TVR seems to occur when the initial contraction level is high (20% MVC) or at a large vibration amplitude (300 mm). Nevertheless, the amplitude of the TVR component appears to be primarily a function of the vibration frequency. The shape of this function is highly correlated to the sensitivity of the proprioceptive muscle receptors to the vibratory stimulus (Vedel *et al.*, 1985). The slight difference in the "cut-off" frequency of the TVR elicited in the finger and wrist flexor, respectively, and the higher percentage of FDP MU activity synchronized at the VF up to 100 Hz seem to indicate a higher sensitivity of the finger flexor spindle endings. It may result from the functional difference of the two muscles. Indeed, precise regulation of muscle activity, and thus accuracy of proprioceptive feedback, is conceivably more critical for the fingers than the wrist.

The increase of the intensities of the TVR and the MU synchronization with VF up to 80 Hz is likely to result from an increase in depolarization of motoneurons with the firing frequency of Ia afferent fibers, which increases the number of responding motoneurons. Beyond this "cut-off" frequency, driving is less secure, most of the receptors start to misbehave and respond at subharmonic frequencies or at random as shown by Vedel *et al.* (1985) and indicated by the present results. Thus a derecruitment process affecting the motoneurons is likely to occur. It is worth noting that although the strength of the TVR is dependent upon vibration displacement amplitude and muscle contraction level, within the respective ranges, the "cut-off" frequency was not affected by them.

As previously indicated by Lebedev and Polyakov (1992), the surface EMG turned out to be a useful means to analyze MU synchronization since it is noninvasive, and it can be easily used for analysis of different muscle contraction levels, while single MU technique might have some difficulties at high muscle contraction levels.

Furthermore, these results indicate that high frequency vibration (> 150 Hz) tends to induce less muscle/tendon stress, as well as, less MU synchronization. Such remarks are of particular importance for the design of hand-held vibrating tools.

REFERENCES

Lebedev M.A. and Polyakov A.V. (1992). *J. Electromyogr. and Kines.* **2**, 1-10.
Park, H. S. and Martin, B. J. (1993) *Scand. J. Work, Environ. Health*. (in press).
Romaiguere P, Vedel, J. P., Azulay, J. P. and Pagni S. (1991) J. *Physiol.* **444**, 645-67.
Vedel, J. P., Roll, J. P. and Ribot, E. (1985) In: *Man under vibration* . Frolov, K. V. (ed)