Vibromyographic recording from human muscles with known fibre composition differences

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Abstract

Objective—To determine the relation between the vibromyographic (VMG) frequency characteristics and fibre composition in postural and non-postural human muscle undergoing a standardised voluntary contraction.

Methods—Two human muscles with different fibre compositions [soleus: postural, mainly type I (slow) fibres; biceps brachii: non-postural, mixed type I and II (fast) fibres] were recorded from 18 healthy males isometrically contracting at 50% of their maximum voluntary contraction (MVC). Muscle vibrations were recorded using a contact microphone and the frequency content of the signals calculated using fast fourier transform algorithms.

Results—The non-postural biceps brachii showed predominantly bimodal power spectra with significantly increased power in the 10-30 Hz bands (P < 0.01), as compared with soleus recordings which tended to be unimodal, with the majority of power below 10 Hz.

Conclusions—Muscles with a large proportion of type I fibres generate VMG signals which contain an increased percentage of low frequencies compared to muscles with a mixed population of type I and type II fibres. The VMG appears to be generated, in part at least, by the mechanical twitching of motor units within the muscle; frequency domain analysis of this signal may provide a non-invasive measure of muscle fibre composition.


Key terms: muscle; vibromyography; fibre type; sound

Contracting muscles vibrate. This vibration can be detected at the surface of muscle by a variety of transducers, the most commonly employed being contact microphones and, more recently, accelerometers.1 2 This signal has been increasingly characterised over the last decade since the re-emergence of interest in this phenomenon with the publication of a Scientific American article in 1984.3 The detection and measurement of this signal has been referred to as acoustic myography (AMG),4 phononomyography (PMG),5 6 and vibromyography (VMG).7 8 Initial investigations gave conflicting results, largely because of lack of standardisation of measurement and, particularly, of transducers.10 However, con-
sensus is emerging as standardisation and an increasing number of investigations add to the body of knowledge that describe this signal.

First described in the 16th century, interest in the phenomenon was sparse until the mid-1980s. Initial theories about the aetiology of the vibration included physiological tremor,11 radial expansion of the muscle fibres,12 or lateral vibration of the muscle body.13 14 Support for the notion of gross lateral motion of the muscle as the major source of vibration came from experiments performed in vitro using isolated preparations of frog muscle which were unlikely to mimic the more complex vibrations of muscle in situ. Early areas of interest were the relationship of the signal to force15 16 and its behaviour during muscle fatigue.4 17 However, several investigators have suggested that the vibration is a composite mechanical signal generated by the asynchronous contraction of motor units within the muscle. It is possible, therefore, that the signal may contain information as to fibre type composition and recruitment strategies.18 20

The aim of this investigation was to ascertain the existence of any consistent relationship between the frequency characteristics of VMG and the fibre composition found in postural and non-postural human muscle undergoing a standardised voluntary contraction.

Methods

Eighteen healthy male subjects were included in this study, with an age range of 20–40 years. Maximum voluntary contraction (MVC), or one repetition maximum (1RPM), was determined for each subject before the recording and 50% of this value was used during acquisition of the signal.

EXPERIMENTAL PROCEDURES

The muscles of choice in this experiment were biceps brachii and soleus.

Biceps brachii was isolated in a seated subject whose elbow was flexed at 90° holding a weight (fig 1). The weight was increased until the test position could not be held and this value taken as 1RPM. At 50% of this value, recording of VMG was achieved by taping the transducer to the mid-belly region of the lateral head of the biceps.

The soleus was isolated by seating the subject with both hip and knee flexed to 90° with the foot in plantar flexion through approximately half its range of motion. Determination of 100% MVC was achieved by the subject actively plantar flexing against a
commercial scale while the knee was rendered immovable (fig 2). The transducer was taped over the lateral aspect of the soleus inferior to the belly of the gastrocnemius.

**SIGNAL ACQUISITION AND ANALYSIS**

Four-second duration VMG recordings were acquired from subjects undergoing isometric contractions at 50% MVC. Signals were detected using a piezoelectric contact microphone which consisted of a disc (diameter 2 cm) taped to the muscle with micropore tape. The signal was preamplified (Harvard AC-DC) and filtered (40 Hz low pass). The signal was digitised at 1 kHz (DTR2821 AD) using a 286 processor PC. Analysis and display was achieved using commercial signal acquisition software (SIGNALYS: Ziegler).

Off-line analysis consisted of further filtering (3 Hz high pass FIR filter) to remove arterial sounds. Filtered raw signal amplitude was determined by measurement of individual root mean square (RMS) values. Fast Fourier transforms (4096 points) were used to generate power spectra normalised to the maximum peak. Individual power spectra were integrated and the per cent power present in 5 Hz bands determined. Differences in amplitude or per cent power content in equivalent bands for biceps brachii and soleus were calculated using the paired Student t test.

**Results**

Figure 3 shows the filtered signal from both biceps and soleus. Figure 4 illustrates the power spectra of soleus and biceps recordings from six individual subjects. It is clear that a consistent difference is the absence of significant power in soleus recordings above 10 Hz, as compared with the equivalent biceps signal. In addition, it appears that those individuals with wide bands of frequency show this tendency in both soleus and biceps. The power present in 5 Hz bands was determined by integration of the power spectra and the mean values determined for both soleus and biceps (table). Two important differences in the frequency content of the two muscles are apparent. The first is the increased power present in the 5–10 Hz band in soleus muscle.

<table>
<thead>
<tr>
<th>Frequency bands (Hz)</th>
<th>Mean iVMG as % of total power</th>
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<tbody>
<tr>
<td></td>
<td>Biceps brachii</td>
</tr>
<tr>
<td>&lt;5</td>
<td>11·4 (4·6)</td>
</tr>
<tr>
<td>5–10</td>
<td>43·9 (9·5)</td>
</tr>
<tr>
<td>10–15</td>
<td>26·3 (8·0)</td>
</tr>
<tr>
<td>15–20</td>
<td>10·0 (6·9)</td>
</tr>
<tr>
<td>20–25</td>
<td>3·4 (2·1)</td>
</tr>
<tr>
<td>&gt;25</td>
<td>4·9 (4·2)</td>
</tr>
</tbody>
</table>

*Significantly different between biceps and soleus power in these bands (P < 0.01) using a two tailed unpaired t test.
Vibromyographic recording from muscles of different fibre composition

This situation is reversed in biceps, where an increase in power is present in bands from 10–25 Hz. This was confirmed when all individual power spectra were averaged using software (fig 5). In addition, it is clear that the biceps displays a distinctly bimodal shaped spectrum, as opposed to the soleus which shows significant frequencies only in the low band. It appears that the high band present in biceps power spectrum is not present in soleus recordings.

It is apparent from fig 4 that considerable variation may be present between individuals. However, fig 6 illustrates the consistency within an individual where recordings were made at three different sessions separated by 2 d. The individual spectra are consistent for an individual’s muscle, with the differences between soleus and biceps remaining within an individual.

Discussion
The fibre composition of human soleus muscle is approximately 70% slow (type I) fibre, whereas biceps, on average, contains equally mixed slow and fast (type II) fibres. Our results suggest that VMG can resolve consistent differences between muscles. This appears to be true for similar length muscles which are being loaded to the same per cent MVC. Previous studies using VMG recordings from different muscles have not stipulated the load on each muscle. This is particularly important, as the shape of the power spectrum changes with increasing contraction levels. A recent study, using stimulation to elicit muscle twitches in vastus lateralis and soleus, has shown that the frequency of these signals, detected using a contact microphone, reflects the fibre composition of the relevant muscle. In addition, a preliminary study of orbicularis oris and soleus indicated differences in mean frequency of these two muscles and it was...
suggested that this might be related to fibre composition.\textsuperscript{29} Another study has indicated that muscle fibre typing differences found in vastus lateralis of sprinters and long distance runners are reflected in the VMG characteristics showing fatigue.\textsuperscript{28}

It has been shown that the signal amplitude can be affected by the degree of pressure exerted on the microphone.\textsuperscript{10} \textsuperscript{27} However, there were no significant differences in signal size from biceps or soleus recordings. It is clear that the major differences are seen in the frequency domain, these being apparent in individual recordings as well as in the averaged power spectra, albeit with more variation in the former. Such variability between individuals may indicate a possible source of the VMG signal, that is, differences in fibre type activity. That fibre type activation can cause changes in the VMG power spectra has been shown.\textsuperscript{20} \textsuperscript{25} These studies have consistently shown shifts to higher frequencies with increases in intensity of muscle contraction, as might be the case with a greater contribution by type II fibres with increasing force generation.\textsuperscript{24} It is interesting to note that individuals who display wide frequency spectra in biceps also have higher frequencies in soleus as compared to individuals who display narrow band frequencies in biceps and therefore a narrow band soleus. This has been noted before in EMG power spectra\textsuperscript{22} and may reflect idiosyncratic fibre composition. This unique composition is thought to be genetic in origin.\textsuperscript{23} A possible application of this is in sport, where individual differences in either fibre composition or recruitment strategy may be detectable. That training can affect the VMG power spectra has already been indicated.\textsuperscript{26}

\textbf{CONCLUSION}

The results of this study appear to indicate that muscles with a large proportion of slow (type I) fibres generate VMG signals which contain a significantly increased percentage of low frequencies compared with muscles with a mixed population of fast (type I) and slow (type II) fibres. These results, together with those of other workers, appear to support the notion that VMG is, in part at least, generated by the mechanical twitching of motor units within the muscle, and that frequency domain analysis of this signal may provide a non-invasive measure of muscle fibre composition.

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Vibromyographic recording from muscles of different fibre composition