Effect of step and ramp static contraction on the median frequency of back muscles

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Introduction

The median frequency (MF) of the electromyographic (EMG) power spectrum is potentially sensitive to the fibre type content of a given muscle [4]. This characteristic would be useful in the evaluation of back muscles of chronic low back pain (CLBP) patients for which changes in muscle composition are observed [6]. However, the MF/Force relationship is dependent on the mode of contraction used (step vs ramp) in the upper limb muscles [1,8]. Thus, the purpose of this study was to compare the MF/Force relationship of four pairs of back muscles for two contraction modes (step vs ramp).

Methods

Subjects and tasks

Twenty healthy males (Age: 25, SD 4 yr; Height: 1.77, SD 0.06 m; Mass: 72, SD 9 kg) stood in a dynamometer with the trunk in a vertical position (Fig. 1). They performed static trunk extension efforts using the displayed L5/S1 extension moment as visual feedback [5]. Two 7 s static ramp contractions ranging from 0 to 100% of the maximal voluntary contraction (MVC) and two 6 s static step contractions at five force levels (10, 20, 40, 60 and 80% MVC) were performed. The step contractions followed the ramp contractions but were counterbalanced using a Latin Square design.

Electromyography

The EMG signals from four pairs of back muscles (Fig. 2.) were collected (bandpass filter: 20-450 Hz; preamplification gain: 1000; sampling rate: 4096 Hz) with active surface electrodes (Delsys Inc., MA). The MF (250 ms windows, 1024 points; Hamming window, fast Fourier transform) and the corresponding root mean square (RMS) values of the EMG signals were computed at each force level for both contraction modes and averaged across the two trials. For ramp contractions, the position of the windows was selected automatically according to the force level and then moved backward in time by 130 ms to take into account the electromechanical delay [11]. For step contractions, the window was visually determined according to the quality of the L5/S1 extension moment in the middle of the step contraction (approximately at 3 s).

Statistics

Statistical analyses were performed with two-way ANOVAs (2 Contraction modes x 5 Force levels) with repeated measures (α = 0.05) on both factors. When necessary, post hoc analyses were performed with multiple paired t-tests comparisons and the significance level was adjusted using the Bonferroni technique.
**Results**

**Comparison of relative force levels between step and ramp contractions:**
The maximal L5/S1 extension moments performed at the beginning of the protocol and used as the MVC in the present study averaged –264 Nm (SD, 50 Nm). The average relative force level values of 9.8 (SD, 0.2), 19.9 (SD, 0.4), 39.7 (SD, 0.6), 59.1 (SD, 0.9) and 79.0 (SD, 1.0) sustained during step contractions were comparable to the targeted % MVC (10, 20, 40, 60 and 80% MVC) and the standard deviations were small.

**Comparison of RMS and MF values between step and ramp contractions:**
The RMS results for the ramp contractions were significantly higher than for step contractions this for six muscles (Table 1). However, the differences were small (from 3 to 10 µV). The corresponding MF values showed a significant Contraction mode × Force level interaction for four muscles (MU-L5-L & R, IL-L3-R, LO-L1-L) (Table 1, Fig. 3). These interactions generally showed that the increase of the MF was prolonged to higher force levels during ramp contractions (to 40-60% MVC) than during step contractions (to 20% MVC) before levelling off or decreasing at high force levels. A significant Contraction mode main effect was detected for four muscles (IL-L3-L & R, LO-L1-R, and LO-T10-L) with higher MF values during step than during ramp contractions. However, as determined with post hoc analyses (Fig. 3), these differences were more obvious (10-15 Hz) and more frequent at lower (10, 20 and 40% MVC) force levels.

**Table 1. Summary (P probability values) of two-way ANOVAs (2 contraction modes × 5 force levels) for repeated measures performed on the RMS and MF values for each muscle.**

<table>
<thead>
<tr>
<th>Muscle</th>
<th>RMS</th>
<th>MF</th>
<th>RMS</th>
<th>MF</th>
<th>RMS</th>
<th>MF</th>
</tr>
</thead>
<tbody>
<tr>
<td>LO-T10-L</td>
<td>0.425</td>
<td>0.009</td>
<td>0.000</td>
<td>0.436</td>
<td>0.343</td>
<td>0.222</td>
</tr>
<tr>
<td>LO-T10-R</td>
<td>0.942</td>
<td>0.118</td>
<td>0.000</td>
<td>0.568</td>
<td>0.103</td>
<td>0.413</td>
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<tr>
<td>LO-L1-L</td>
<td>0.000</td>
<td>0.085</td>
<td>0.000</td>
<td>0.036</td>
<td>0.004</td>
<td>0.036</td>
</tr>
<tr>
<td>LO-L1-R</td>
<td>0.000</td>
<td>0.018</td>
<td>0.000</td>
<td>0.027</td>
<td>0.019</td>
<td>0.084</td>
</tr>
<tr>
<td>IL-L3-L</td>
<td>0.005</td>
<td>0.002</td>
<td>0.000</td>
<td>0.001</td>
<td>0.001</td>
<td>0.062</td>
</tr>
<tr>
<td>IL-L3-R</td>
<td>0.001</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.003</td>
<td>0.000</td>
</tr>
<tr>
<td>MU-L5-L</td>
<td>0.000</td>
<td>0.563</td>
<td>0.000</td>
<td>0.005</td>
<td>0.698</td>
<td>0.006</td>
</tr>
<tr>
<td>MU-L5-R</td>
<td>0.000</td>
<td>0.236</td>
<td>0.000</td>
<td>0.000</td>
<td>0.979</td>
<td>0.046</td>
</tr>
</tbody>
</table>

*The significant differences (P < 0.05) are identified with bolded characters

The power spectra averaged across subjects at 20 and 80% MVC force levels showed, for different muscles, the differences in the MF between the two contraction modes. A peak in the 20-50 Hz frequency band of the power spectra was observed and this peak was larger for the ramp than for the step contraction, especially at 20% MVC. The mode frequency of this peak was around 28 to 33 Hz.

**Discussion**

The small RMS differences observed in the present study were mostly constant across the force levels making their implication unlikely in the large MF differences observed at the low force levels only. The significant Contraction mode × Force level interactions contrasted with one study [3] but concurred with three other studies for different muscles [1,7,8]. Assuming that the contribution of each back muscle agonist to the net L5/S1 extension moment was approximately the same for each contraction mode (Fig. 3) and considering the low rate of force increase during the ramp contractions, it appears unlikely that different
Fig. 3.
Median frequency values (Hz) computed for each muscle as a function of force level and contraction mode (ramp: o; step: *).
The + signs identify the force levels where a significant difference occurs between contraction modes.

motor units involving systematically different recruitment thresholds and firing patterns were used to produce muscle forces [2].

The visual analysis of the power spectra revealed a mode frequency around 28 to 33 Hz. Interestingly, van Boxtel & Schomaker [9] observed well defined peaks between 20 and 37 Hz depending on the muscle investigated. These peaks are attributed to the firing of the first recruited low-threshold motor units at a common firing frequency called “dominant firing rate” [10]. Such peaks decrease the MF to lower values especially at low force levels [10], an observation that applies to the results of the present study. However, this phenomenon has been described only for subjects with and without firing rate peaks [10] so it is not known if it is task dependent as suggested in the present results.

In summary, the presence of a different behaviour of the MF across force levels was observed between two contraction modes for different back muscles. The discrepancies between MF results were generally observed at lower force levels (< 50% MVC). Mechanisms not related to motor unit recruitment might influence the MF in one or both contraction modes. In a context of the use of EMG spectral parameters as a non invasive alternative to muscle biopsy, the mode of contraction that could provide the best physiological link with the recruitment pattern of muscle fibres is required. However, because these mechanisms are yet to be defined, it was not possible to favour one contraction mode over the other from the present results.

References

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