Force and EMG-changes during repeated fatigue tests in rat fast muscle

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Introduction

It is well known that, after common types of fatigue test, part of the recovery of force generation happens within seconds or minutes whereas other recovery processes are exceedingly slow (e.g. the 'low-frequency fatigue' of partly fused contractions; Edwards et al. 1977). This slow recovery, which may require several hours, makes it difficult to repeat tests in the same muscle or muscle unit for comparisons of the full fatiguing effects of different activity patterns. Hypothetically, fatigue processes of (moderately) rapid recovery characteristics ('fast-fatigue') might be studied separately in fatigue tests repeated at relatively brief intervals if:

(i) the initial fatigue test(s) could, as it were, be made to 'saturate' the fatigue process of slow recovery ('slow-fatigue') and
(ii) the recovery processes of slow- and fast-fatigue had widely different time constants.

Inspired by such ideas we explored whether, following initial 'priming' fatigue tests, moderately long test intervals in subsequent tests might evoke a constantly repeated pattern of fast-fatigue. Initial experiments indicated that a test interval of 20 min was too brief for a stationary result. The present report concerns repeated tests at 1 hr intervals.

Methods

The experiments were performed on the extensor digitorum longus muscle (EDL) of male adult rats (n=6; weights 320-380 g) anaesthetized with pentobarbitone. EDL was directly connected with a force transducer and kept at the optimum length for twitches. The muscle was activated via supramaximal electrical stimulation of muscle nerve. Electromyogram (EMG) was recorded via two bared thin wires thrust into the muscle belly. Nerve and muscle were covered with warm paraffine oil (36-38°C).

At intervals of 1 hr the following series of stimulations was repeated 6 times: (i) 10 single stimuli for evoking twitches; (ii) one burst of 200 Hz (duration 1 s) for evoking a maximum tetanic contraction; (iii) a fatigue test (cf. Burke et al. 1973) consisting of bursts of 40 Hz (duration 0.33 sec) repeated once a second for 4 minutes (totally 240 bursts). Peak forces were measured for contractions evoked by single or repetitive stimulation. All forces were expressed in relation (%) to that of the maximum tetanic contraction preceding the initial fatigue test ('test 1'). In the EMG, peak-to-peak amplitudes were measured for the evoked compound action potentials (M-waves).

Results and conclusions

The 1 hr test interval was sufficient for producing a full inter-test recovery of maximum tetanic force (Table 1). During test 1 there was a considerable initial force-potentiation (peak at around 20 s). This potentiation showed a very slow recovery; the peak force during potentiation was considerably smaller in tests 2-6 than in test 1 (Fig.1).

As seen during the later halves of consecutive fatigue tests, there was no progressive deterioration of force generation but rather, paradoxically, the contrary (Table 1, Fig.1). A qualitatively similar (and even more marked) tendency for a progressive increase was seen in the late EMG-reactions (Table 1).
Table 1. Contractile and EMG parameters per fatigue-test.

All force values expressed in per cent of the maximum tetanic force of test-1. EMG amplitudes (first M-wave per burst) given in per cent of M-wave amplitude for the first burst of test-1. Final force and EMG values refer to last burst of the respective fatigue test (i.e. value at 4 min after test start). Means±SD (n=6 tests).

<table>
<thead>
<tr>
<th>Test no.</th>
<th>Tetanic force (%)</th>
<th>Twitch: Tetanus (%)</th>
<th>Final force (%)</th>
<th>Final EMG (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-1</td>
<td>100</td>
<td>14.2±2.5</td>
<td>4.8±4.0</td>
<td>26.5±6.8</td>
</tr>
<tr>
<td>T-2</td>
<td>100±16</td>
<td>9.9±2.4</td>
<td>5.6±3.3</td>
<td>29.9±9.6</td>
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<tr>
<td>T-3</td>
<td>99±12</td>
<td>9.8±3.0</td>
<td>10.0±2.1</td>
<td>52.7±9.9</td>
</tr>
<tr>
<td>T-4</td>
<td>99±12</td>
<td>8.7±2.7</td>
<td>10.8±2.8</td>
<td>59.8±16.1</td>
</tr>
<tr>
<td>T-5</td>
<td>102±10</td>
<td>7.7±2.5</td>
<td>9.8±2.5</td>
<td>61.2±15.6</td>
</tr>
<tr>
<td>T-6</td>
<td>96±9</td>
<td>7.2±2.4</td>
<td>8.0±1.9</td>
<td>64.8±19.5</td>
</tr>
</tbody>
</table>

Following test 3, the force-reponses remained relatively similar during consecutive tests, particularly in later test-portions (Table 1, Fig.1). Simultaneously with these semi-stationary force responses during tests 3-6 there was, however, a significant progressive decrease in twitch amplitude (Table 1; paired t test for T-3 vs. T-6, P<0.01).

The semi-stationary force responses seen during the present kind of 'Burke-tests' repeated every 1 hr might provide a suitable background for testing the effects of different activation patterns on 'fast-fatigue'. It should be realized, however, that the apparently similar force-behaviour of fatigue tests 3-6 is likely to reflect a complex balance between several continuously changing parameters of importance for muscle force.

Figure 1. Time course of changes in peak burst force during consecutive fatigue tests (see T-1 to T-6 in symbol legend). All forces expressed in relation (%) to that for the maximum tetanic contraction preceding test T-1.

References
