Reaction of end-plate potentials in slow and fast rat muscle during fatigue-test stimulation

O. Eerbeek and D. Kernell

Department of Neurophysiology, Academisch Medisch Centrum, University of Amsterdam, Meibergdreef 15, 1105 AZ Amsterdam, The Netherlands.

It is well known that, during electrically induced fatigue tests, a decline in force ('force fatigue') is commonly associated with a decrease in amplitude of the evoked compound action potentials ('EMG depression'). In rats, the slowly contracting soleus muscle (Sol) is more resistant to both force fatigue and EMG depression than the fast extensor digitorum longus muscle (EDL) (e.g. Enoka et al. 1989; cf. Figs.1A, 2A). As part of our efforts to elucidate the possible causes for these differences in EMG-depression, we have now compared the two muscles with regard to the fatigue-test associated behaviour of their end-plate potentials (EPPs).

Nerve-muscle preparations from normal adult rats (250-300 g body weight) were mounted in an in vitro chamber, which was perfused at a rate of 30-40 ml/min with Krebs solution (35-37°C, pH 7.38) that was continuously bubbled with carbogen. The muscle was split at the nerve entry and an innervated strip of muscle tissue was spread out and fixed with small steel needles on a ribbed block of silicon rubber. To prevent nerve stimulation from eliciting muscle fibre action potentials and contractions the tissue was pinched with a pair of small tweezers, beginning at the distal ends of the strip ('cut fibres', cf. Gertler & Robbins, 1978). Intracellular recordings were obtained with glass microelectrodes (4-10 MΩ) filled with 3M KCl. Recordings were rejected if: (i) the initial membrane potential was less negative than -50 mV; (ii) membrane potential decreased by more than 20% from its initial value. All penetrations were from fibre regions with visible miniature end-plate potentials. Full-size EPPs were elicited by electrical stimulation of the nerve (0.1 ms pulses). Recordings from penetrated muscle fibres included: (a) five initial single EPPs (stimulation at 0.5 Hz); (b) EPPs obtained during fatigue-test stimulation of *either* 40-Hz bursts of 0.33 sec repeated once a sec during 2 min *or* 80-Hz continuous stimulation during 30 sec; (c) after 1 min rest: five single EPPs.

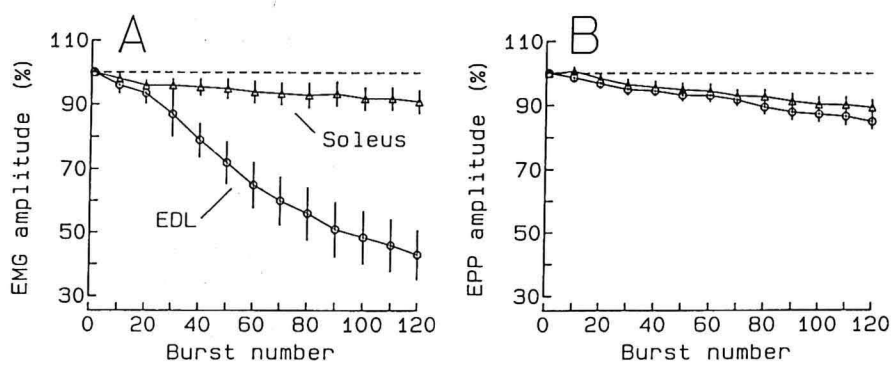

Figure 1. Relative changes (%; means±SE) of EMG and EPP amplitude during 40 Hz fatigue test stimulation (bursts) lasting 2 min. **A** Peak-to-peak sizes of compound action potentials (M waves), as recorded in vivo from 6 Sol and 7 EDL muscles. **B** EPP amplitudes for 12 Sol and 11 EDL muscle fibres, as recorded intracellularly in vitro. Interrupted lines drawn at y = 100%.

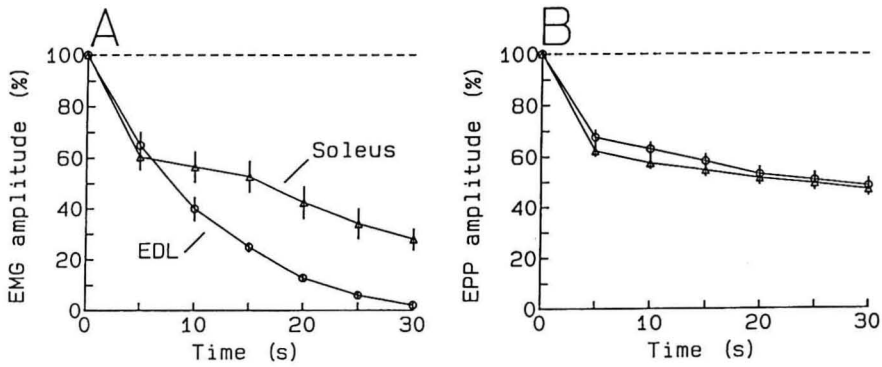

Figure 2. Display as in Fig.1, but for 80-Hz continuous fatigue-test stimulation. **A** From 6 Sol and 6 EDL muscles. **B** From 18 Sol and 13 EDL muscle fibres.

Our results showed that, during either type of fatigue-test stimulation, the mean decline of EPP amplitude was the same for fibres from Sol and EDL (40-Hz test, Fig.1B; 80-Hz test, Fig.2B). Following either test procedure, 1 min rest was sufficient for a full post-stimulation recovery of EPP amplitude.

The mean initial EPP size was significantly greater for Sol (14.6±3.8 (S.D.) mV, n=27) than for EDL (10.1±3.8 mV, n=20; t test, $P<0.001$). With regard to the EPP time course or the resting membrane potential (average -57 mV), no significant differences were found between Sol and EDL.

Our results indicate that the differences in EMG depression between Sol and EDL (Figs.1A, 2A) were not caused by differences in the fatigue-test associated decline of EPP sizes (Figs.1B, 2B). The differences in EMG depression might still have been caused by a greater safety of neuromuscular transmission for Sol than for EDL if the initial amount of excess EPP size, above the threshold for action potential initiation, were normally greater for Sol than for EDL. Alternatively (or additionally), the differences in EMG depression (Figs.1A, 2A) might have been caused by differences in a fatigue-associated decline of the amplitude of sarcolemmal action potentials.

In the intracellular end-plate studies of Gertler & Robbins (1978) and Lev-Tov (1987), certain differences in EPP-behaviour were indeed observed between Sol and EDL. However, the test stimulation procedures of these investigations were different from the present ones. Still, the observations of Gertler and Robbins (1978) on curarized fibres seem consistent with the present findings; in their cases a continuous 40-Hz stimulation (200 pulses) caused a depression of about the same relative magnitude in Sol and EDL (quantum content down to 20.7% of initial value in curarized Sol and to 21.9% in curarized EDL; in 'cut fibres', however, depression was to 42.7% in Sol and to 32.2% in EDL). The study of Lev-Tov (1987) differs fundamentally from the present one by specifically concerning the *potentiating* EPP behaviour that becomes revealed when quantum content is kept low.

References

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