Interaction of fibre type, potentiation and fatigue in human knee extensor muscles

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Abstract
Aim: To examine the effect of fibre type on potentiation and fatigue.
Methods: Young men ($n = 4$ per group) with a predominance of type I [61.4 ± 6.9% (SD), group I (GI)] or type II [71.8 ± 9.2%, group II (GII)] fibres in vastus lateralis, performed a fatigue protocol of sixteen 5-s maximal voluntary isometric contractions (MVCs) of the right knee extensors. Maximal twitches and corresponding muscle action potentials (M-waves) were evoked before the first MVC, during the 3-s rest period after each MVC and at intervals during the 5-min recovery period after the last MVC.
Results: Group II [49.3 ± 2.6% (SE)] had a greater decrease in MVC force than GI (22.8 ± 6.2%) during the fatigue protocol. Group II (126.4 ± 13.6%) showed greater twitch force potentiation early in the fatigue protocol than GI (38.2 ± 2.3%), but greater depression at the end (33.7 ± 13.7% vs. 17.4 ± 3.4%). Twitch time-to-peak torque (TPT) and half relaxation time (HRT) initially decreased but then increased as the fatigue protocol progressed; GII had a greater increase in HRT. During a 5-min recovery period twitch force increased above the prefatigue level and remained so until the end of the recovery period; the pattern was similar in GI and GII. Twitch TPT and HRT remained elevated during recovery. M-wave area increased throughout the fatigue protocol and the first part of recovery before returning to baseline values in GII, whereas there were no significant changes in GI. The interaction between potentiation and fatigue was amplified in GII early in the fatigue protocol with concurrently greater twitch and M-wave potentiation, and greater MVC force decrease and HRT increase. Late in the protocol, GII had a greater decrease in twitch and MVC force combined with greater M-wave potentiation.
Conclusion: It is concluded that fibre type distribution influences potentiation and fatigue of the twitch, and potentiation of the M-wave during fatiguing exercise.

Keywords  isometric contraction, muscle action potential, twitch contraction.
because fatigue exceeds potentiation (Vandervoort et al. 1983, Houston & Grange 1990).

The most important muscle characteristic affecting the interaction between potentiation and fatigue is fibre type. Fast, type II fibres show greater PAP (Moore & Stull 1984, Hamada et al. 2000) but are more susceptible to fatigue (Barclay 1996, Wretling et al. 1997) compared with slow, type I fibres. In muscles with a predominance of type II fibres, whether potentiation or fatigue prevails again depends on contractile history. When the aforementioned 10-s MVC is the prior conditioning activity, the response is greater PAP in muscles with a higher percentage of type II fibres (Hamada et al. 2000).

An experimental protocol that produces an initial potentiation of twitch force followed by depression (fatigue) is a series of brief MVCs (Hicks et al. 1991). Twitch contractions interposed in the rest intervals between MVCs show progressively increased force (potentiation) over the first MVCs, but then twitch force declines (fatigue), eventually falling below that of the pre-activity baseline twitch. This pattern of results can be interpreted as potentiation being greater than fatigue in the first contractions, but increasing fatigue would then cause force depression.

Based on our previous study (Hamada et al. 2000), we would expect muscles with a higher percentage of type II fibres to exhibit greater PAP after the first few contractions of a fatigue protocol consisting of a series of MVCs. However, it is an open question as to how long the greater PAP could be sustained, because type II fibres are also more susceptible to fatigue. Therefore, one purpose of the present study was to assess the effect of fibre type distribution on the interaction between potentiation and fatigue. A brief report (abstract) of this part of the study has been published previously (Hamada et al. 1998).

Similar to the muscle twitch contraction, the associated muscle compound action potential or M-wave is also affected by the activation history of the muscle. For example, the peak-to-peak amplitude of the M-wave may increase (Duchateau & Hainaut 1984, Hicks et al. 1989, Fuglevand et al. 1993, Cupido et al. 1996, McFadden & McComas 1996, Behm & St-Pierre 1997, Galea 2001) or decrease (Hultman & Sjoholm 1983, Bellemare & Garzaniti 1988, Fuglevand et al. 1993, Cupido et al. 1996, Behm & St-Pierre 1997) during or after muscle activity. The fate of the M-wave depends on the intensity and duration of the muscular activity (Moritani et al. 1985, Cupido et al. 1996, Behm & St-Pierre 1997), whether the activity is sustained or intermittent (Duchateau et al. 1987), and on the type of muscle action (e.g. concentric vs. eccentric) (Hortobagyi et al. 1996).

The response of the M-wave to activity also depends on the characteristics of the muscle (Behm & St-Pierre 1997), most notably its fibre type composition (Hamada et al. 2000). Muscles with a higher percentage of fast, type II fibres, and fast motor units within a muscle, may exhibit both greater potentiation (Duchateau & Hainaut 1985, Sandercock et al. 1985, Enoka et al. 1992, Hamada et al. 2000) and fatigue-induced depression (Enoka et al. 1992) of the M-wave or motor unit action potentials during and following different types of activity. We have shown previously that M-wave potentiation is greater in muscles with a higher percentage of type II fibres, following a 10-s MVC (Hamada et al. 2000). We expected, therefore, that these muscles would show greater potentiation after the first few contractions of a fatigue protocol. Similar to the twitch contraction force, however, it was uncertain whether the greater M-wave potentiation would be sustained as fatigue developed later in a fatigue protocol. Thus, the second purpose of the present study was to assess the effect of fibre type distribution on the interaction between potentiation and depression of the M-wave in a fatigue protocol.

**Methods**

**Subjects**

From an initial sample of 20 young men, four subjects demonstrating the highest and four showing the lowest PAP of the knee extensor muscles were selected for the present study. A 10-s MVC had been used to induce PAP and the magnitude of PAP was measured as the amount (%) by which post-MVC twitch peak torque exceeded the pre-MVC baseline twitch value. The subgroups subsequently underwent percutaneous needle biopsies of vastus lateralis for the determination of muscle fibre type distribution. The details of this phase of the study have been published previously (Hamada et al. 2000). It was found that the subgroup with higher PAP had a greater percentage of fast, type II fibres and percentage type II fibre area (percentage of whole muscle area occupied by type II fibres). The characteristics of the subgroups, referred to as GI and GII to denote a predominance of type I and type II fibres, respectively, are given in Table 1. All subjects participated with informed written consent, and the study was approved by the McMaster University Ethics Committee.

**Experimental design**

To study the interaction between potentiation, fatigue and fibre type distribution, muscle twitch and voluntary contraction fatigue responses were obtained from the whole quadriceps, whereas feasibility dictated that fibre type distribution was determined from only one of the
Table 1  Characteristics of the subjects

<table>
<thead>
<tr>
<th></th>
<th>GI (n = 4)</th>
<th>GII (n = 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (year)</td>
<td>21.5 ± 1.3</td>
<td>22.8 ± 3.0</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>171.6 ± 4.9</td>
<td>181.5 ± 8.5</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>69.5 ± 8.5</td>
<td>81.5 ± 5.7</td>
</tr>
<tr>
<td>PAP (%)</td>
<td>42.8 ± 6.6</td>
<td>103.7 ± 11.2***</td>
</tr>
<tr>
<td>Fibre type distribution (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type II</td>
<td>38.6 ± 6.9</td>
<td>71.8 ± 9.2**</td>
</tr>
<tr>
<td>Type IIA</td>
<td>28.6 ± 2.7</td>
<td>45.6 ± 8.8*</td>
</tr>
<tr>
<td>Type IIB</td>
<td>10.1 ± 5.8</td>
<td>26.2 ± 7.3*</td>
</tr>
<tr>
<td>Type II area</td>
<td>41.4 ± 8.6</td>
<td>78.8 ± 5.6***</td>
</tr>
</tbody>
</table>

GI, group with predominance of type I fibres; GII, group with predominance of type II fibres; PAP, post-activation potentiation. PAP was induced by a 10-s MVC; values from knee extensors (Hamada et al. 2000). Fibre type distribution values from vastus lateralis were determined by histochemistry (Hamada et al. 2000). Values are mean ± SD. *P < 0.05, **P < 0.01, ***P < 0.001 for difference between GI and GII.

Post-activation potentiation, fatigue and fibre type

constituent heads, vastus lateralis. Therefore, the study carried the assumption that fibre type distribution of vastus lateralis is representative of the entire quadriceps.

The support for this assumption is that group GII, with a high percentage of type II fibres in the vastus lateralis, also had, for the quadriceps as a whole, characteristics expected of muscles with a predominance of type II fibres; namely shorter twitch time-to-peak torque (TPT) and greater PAP (Hamada et al. 2000), and greater fatigue in repeated MVCs (see Fig. 1). Thus, it is more likely that GII, compared with GI, had a higher percentage of type II fibres in the three heads of quadriceps for which fibre type distribution was not determined.

Feasibility also dictated that muscle action potential (M-wave) responses be recorded from only one head of quadriceps, vastus medialis. Previously, greater M-wave potentiation in the vastus medialis was shown to be associated with a higher percentage of type II fibres in the vastus lateralis, and shorter TPT and potentiation of twitch force (PAP) of the whole quadriceps (Hamada et al. 2000). We have therefore assumed that the M-wave responses in the vastus medialis would be representative of the whole quadriceps.

Fatigue protocol

A week before the fatigue protocol, subjects attended a familiarization session in which they practiced the protocol and became accustomed to muscle stimulation. On the day of the fatigue protocol, the subjects first sat quietly on the apparatus for 30 min to allow dissipation of any lingering PAP induced by travelling to the lab (walking and stair climbing). [Studies in which a high level of PAP has been induced indicate that the twitch response returns to the pre-activity resting level within 10–20 min (e.g. O’Leary et al. 1997)]. Subjects were also asked to refrain from consuming caffeine in the 24 h prior to the experiment. The fatigue protocol consisted of a series of 16 isometric MVCs of the right knee extensor muscles. Each MVC was sustained for 5 s. A 3-s rest period occurred after each MVC. To assess the effects of potentiation and fatigue mechanisms on twitch force, twitch contractions were evoked before the first MVC (baseline or pre-MVC twitch) and at the 2-s point of the rest interval after each MVC of the first 15 MVCs. The timing of the MVCs and intervening twitch responses was computer-controlled. A timing light instructed the subject when to contract and relax. After the 16th (final) MVC a 5-min recovery period began. During this period, in which the subject sat relaxed, twitches were evoked at 5 s after the last (16th) MVC, at 30 s post-MVC and subsequently at 30-s intervals until the 5-min recovery period had elapsed.

Mechanical recordings

The right knee extensors were tested in a custom-made dynamometer (Hamada et al. 2000). The subject sat on the dynamometer with the back and thighs supported so that the thighs were in the horizontal plane with a trunk–thigh (hip) angle of 100°. Velcro straps across the middle and proximal thigh prevented extraneous movement. The right lower leg was strapped to an aluminium
plate, which was attached to a steel shaft whose axis was coincident with the axis of the subject’s knee joint. The shaft–plate combination was adjusted to set the knee angle to 90°. The steel shaft was instrumented with a strain gauge that sensed the torque developed by isometric actions of the knee extensors. The signal from the strain gauge was amplified and filtered (DC to 200 Hz bandwidth), subsequently digitized (sample rate of 3 kHz) (Model DI420, Dataq Instruments Inc., Akron, Ohio, USA), and analysed with both customized and ACODAS (Dataq Instruments Inc.) software on an IBM-compatible personal computer.

**Stimulation**

Twitch contractions of the right knee extensors (quadriceps femoris) were evoked by percutaneous nerve stimulation. Prior to attaching the stimulating electrodes, electrode gel was applied to the contact surface, and the underlying skin was prepared by shaving, sanding and rubbing with isopropyl alcohol. Two carbon-impregnated rubber-stimulating electrodes were used – the cathode (4 × 4.7 cm) placed on the skin over the femoral nerve in the inguinal crease and the anode (4.5 × 10 cm) placed over the mid-portion of the thigh. The stimuli were rectangular voltage pulses of 200 µs duration, delivered from a stimulator (Devices 3072, Medical Systems, Welwyn, Garden City, Herts, UK).

A maximum pre-MVC twitch response was elicited by delivering a series (3–5 s between stimuli) of single stimuli of increasing intensity until a plateau of twitch torque was obtained. The same stimulus intensity (~20% greater than needed for a maximal response) was used for twitch evoked following each MVC in the fatigue protocol and during the recovery period.

**M-wave recordings**

The M-waves associated with the evoked twitch contractions were recorded from one head of the quadriceps, the vastus medialis. This muscle was chosen because the stimulus artefact was smallest at this site, given the position of the stimulating electrodes. Ag/AgCl electromyographic (EMG) disposable recording electrodes, 3.8 mm diameter, were applied to the skin over the belly of the muscle (stigmatic), about 20 mm distal and medial to the patella (reference), and on the post-erolateral aspect of the thigh (ground). Electromyographic signals were amplified (1000×) and filtered (10 Hz–2 kHz). Anologue to digital (AD) conversion and analysis was the same as for torque (see above).

Corresponding to the twitch torque described above, a baseline maximum M-wave was elicited by delivering a series of single stimuli of increasing intensity until a plateau of M-wave amplitude (and associated twitch peak torque) was obtained. The same stimulus intensity (~20% greater than needed for a maximal response) was used for M-waves evoked following each MVC in the fatigue protocol and during the recovery period.

**Measurements and analysis**

Maximal voluntary isometric contraction and twitch contractions were analysed by a custom-designed, computer-based software program. The peak torque of each of the 16 MVCs was measured. Twitch measurements included peak torque, TPT and HRT. M-wave measurements included peak-to-peak amplitude, duration and area.

**Statistics**

To compare the characteristics of GI and GII, a one-factor (between, group) ANOVA was used (Table 1). The results of the fatigue protocol were analysed with a two-factor (between, group; within, time) ANOVA. Data were analysed both in absolute units (e.g. N.m, mV) and in normalized units (percentage changes from the pre-MVC values). However, with the exception of the twitch peak torque, only the results for the normalized units will be reported. Significant main effects for the group and time factors will be referred to as ‘overall’ or ‘combined’ effects. When significant interactions were found, the Tukey post hoc test was used to determine significant differences between group mean values. Statistical significance was set at P ≤ 0.05. Descriptive statistics include mean and standard deviation (SD, in tables) or standard error (SE, in figures).

**Results**

**Maximal voluntary isometric contraction**

The absolute (i.e. expressed in N.m) peak torque of the first MVC in the fatigue protocol was greater in GII than in GI (Table 2). This difference was probably related to GII’s greater body mass (Table 1), because when peak torque was expressed relative to body mass (N.m kg⁻¹), there was no significant difference between the groups (data not shown). During the fatigue protocol, consisting of 16 MVCs, the decrease in MVC peak torque was greater (P < 0.01) in GII (49.3%) than in GI (22.8%) (Fig. 1).

**Twitch peak torque**

The peak torque (P₀) of the control (resting value before first MVC) twitch was greater in GI than GII (Table 2 and value at time 0 in Fig. 2a). The change in absolute P₀ during the fatigue protocol and subsequent recovery
The percentage changes in Pt relative to the control value are shown in Figure 2a. In both groups Pt increased above the control value over the first part of the fatigue protocol but fell below the control value during the second part of the protocol. Group II exhibited a greater early increase and later decrease in Pt than GI. Group II's greater early increase in Pt caused their value to rise above GI's value, despite GII's smaller control twitch. During the 5-min recovery period after the fatigue protocol, Pt increased to and then exceeded the control value in both groups. Group I's Pt remained above GII's throughout the recovery period.

The percentage change in Pt relative to the control value are shown in Figure 2b. A much greater potentiation (increase in Pt) in GII early in the fatigue protocol is highlighted, whereas the fatigue (decrease), although still greater than GI's, does not appear as marked. Group II (126.4%) and GI (38.2%) had their greatest potentiation after the second MVC, whereas their greatest respective decreases were −33.7 and −17.4% after the 15th MVC. During the recovery period Pt again becomes potentiated above the control value (Fig. 2b). Also clearer is the contrast between groups in the magnitude and pattern of recovery. Group I had the greatest recovery value (34.5% above control value) 150 s into recovery (corresponding to 274 s on the time scale in Fig. 2), whereas GII showed the greatest value (39.5%) at the end of the recovery period (300 or 424 s in the time scale of Fig. 2). Group II's potentiation eventually rises to match and finally exceed GI's, although GII's absolute Pt values remain lower than GI's throughout the recovery period.

The vertical dashed line indicates the end of the last (16th) MVC. Horizontal dotted lines indicate significant change (from control value (set to 0), which was the twitch before the first MVC. M-wave values, recorded from vastus medialis, are those associated with the resting twitch values of the entire quadriceps. Values are mean ± SD. *P < 0.05, **P < 0.01 for difference between GI and GII groups.

**Figure 2** Twitch peak torque during the 16 maximal voluntary contraction (MVC) fatigue protocol and subsequent 5-min recovery period. Twitches were evoked at the 2-s point of the 3-s rest period after each MVC. The exception was the twitch after the 16th MVC, which occurred 5 s after the 16th MVC. The vertical dashed line indicates the end of the last (16th) MVC. (a) Twitch peak torque expressed in absolute units (NAm). There was a group × time interaction (P < 0.001). *P < 0.05 for difference between GI and GII groups. (b) Twitch peak torque expressed as percentage change from the control value (set to 0), which was the twitch before the first MVC. Horizontal dotted lines indicate significant change (from zero, P < 0.05) limits for the group × time interaction (P < 0.001). *P < 0.05 for difference between GI and GII groups. GI and GII refer to groups with a predominance of types I and type II fibres, respectively. Values are mean and SE.
evoked 2 s after the MVC. The first twitch in the recovery period was evoked 5 s after the 16th MVC. As seen in the figure, Pt was actually greater after the 16th than after the 15th MVC. The reason for this was the longer rest period before this twitch was evoked (5 s vs. 2 s).

Twitch time-to-peak torque and half relaxation time

Time-to-peak torque of the control twitch was longer in GI whereas there was no group difference in HRT (Table 2). The relative (%) changes in TPT during the fatigue protocol and recovery period are shown in Figure 3a. Twitch TPT at first decreased and then increased during the fatigue protocol and continued to increase during recovery ($P < 0.001$) but the amount or pattern of change did not differ between GI and GII. It appears that the increase was greater in GII during recovery, but an ANOVA carried out on TPT values during this period indicated no difference ($P = 0.12$), probably due to large intersubject variation in GII (see large error bars in Fig. 3a).

The relative changes in HRT are shown in Figure 3b. The amount and pattern of change in HRT differed between groups ($P < 0.001$). Half relaxation time increased significantly during the fatigue protocol; at times the increase in GII was significantly greater than GI. In both groups HRT remained significantly elevated above control at times during the recovery period. There was a ‘cross-over’ in the groups’ patterns. Group II had greater HRT elevation during the fatigue protocol but GI had greater elevation in the recovery period. By the last time point in the recovery period the groups had converged.

M-wave

Resting values of M-wave amplitude, duration and area taken before the first MVC did not differ significantly between GI and GII (Table 2). The relative (%) changes in M-wave amplitude, duration and area during the fatigue protocol and recovery period are shown in Figure 4. M-wave amplitude increased progressively during the fatigue protocol, then decreased during the recovery period and was close to the control value by the end of recovery (Fig. 4a). Although there was a trend ($P = 0.06$) for GII to have a greater increase in M-wave amplitude during the fatigue protocol and recovery period, the pattern of change was similar in the two groups. M-wave duration initially decreased below the prefatigue control value, and then increased until it had returned to the control by the end of the fatigue protocol (Fig. 4b). There was a trend ($P = 0.08$) for a greater elevation of M-wave duration in GII, but the pattern of change was similar in the two groups. The amount and pattern of change in M-wave area differed between GI and GII ($P < 0.001$) (Fig. 4c). Group II’s M-wave area was significantly increased throughout all but the beginning of the fatigue protocol and throughout the entire recovery period. In contrast, GI’s M-wave area did not change significantly at any time during the fatigue protocol and recovery period.
Discussion

Twitch properties

A high percentage of fast, type II fibres (GII vs. GI) was associated with greater twitch potentiation early in the fatigue protocol. The greater initial potentiation was expected, because GII had previously demonstrated greater PAP than GI following a 10-s MVC; indeed, the GI and GII groups had been formed on this basis (Hamada et al. 2000). The purpose of the present study was to determine how long greater PAP in GII (greater percentage increase in twitch torque) could be sustained during a fatigue protocol. We found that type II fibres’ greater susceptibility to fatigue overwhelmed their greater capacity for potentiation after nine of 16 repeated MVCs, after which GII’s twitch force not only fell below the prefatigue value, but also below the corresponding values for GI, whose high percentage of type I fibres conferred less capacity for potentiation but greater resistance to fatigue.

The mechanism of PAP is considered to be phosphorylation of myosin regulatory light chains (R-LC) (Sweeney et al. 1993). The greater PAP observed in fast, type II muscle fibres (Moore & Stull 1984, Hamada et al. 2000) is related to their greater capacity for phosphorylation of R-LC (Moore & Stull 1984). In the present study, GII’s greater PAP was therefore most likely related to their higher percentage of type II fibres. There are several possible mechanisms of fatigue. Twitch contractions, which were used to monitor the interaction between potentiation and fatigue in the present study, are particularly susceptible to impairment of excitation–contraction coupling (Fitts 1994).

The mechanisms responsible for PAP and fatigue can coexist (Rassier & MacIntosh 2000), and in the present study the coexistence was shown in three ways. First, twitch torque increased and remained elevated above the prefatigue value until about halfway through the fatigue protocol, indicative of ongoing potentiation, whereas MVC torque declined steadily during this period, a sign of coexisting fatigue. Secondly, after having been depressed in the second half of the protocol, twitch torque again rose above the prefatigue value during the recovery period, indicating that the mechanism responsible for potentiation was still active but could not manifest itself as PAP until fatigue had to some extent subsided. The third indication of the coexistence of potentiation and fatigue was the pattern of change in twitch duration (TPT and HRT) during and after the fatigue protocol. In unfatigued muscle, twitch potentiation is associated with shortened twitch duration (e.g. O’Leary et al. 1997), whereas fatigue is associated with reduced force and prolonged duration (e.g. Fitch & McComas 1985). At the beginning of the fatigue protocol in the present study, the expected coupling of increased twitch torque and shortening of twitch duration (TPT and HRT), typical of PAP, was found. As fatigue progressed, however, TPT and HRT increased towards the prefatigue value or even became prolonged, although twitch torque remained elevated. The combination of increased twitch torque and...
duration also occurred during recovery after the fatigue protocol. The simultaneous occurrence of twitch force potentiation and increased twitch duration, reported previously (Jami et al. 1983, Kukulka et al. 1986, Rankin et al. 1988), suggests that potentiation and fatigue mechanisms were acting concurrently (Rankin et al. 1988; Rassier & MacIntosh, 2000).

A comparison of GI and GII, representing a predominance of type I (slow) and II (fast) muscle fibres, respectively, indicates that the interaction between potentiation and fatigue was most pronounced in type II fibres. Thus, GII showed both greater PAP early in the fatigue protocol, and greater fatigue (decrease in twitch torque) later in the protocol. Also early in the fatigue protocol, GII simultaneously exhibited both greater PAP and a greater decrease in MVC peak torque. During recovery after the fatigue protocol, GII’s twitch torque increased throughout the recovery period but never approached the high values obtained early in the fatigue protocol, whereas GI’s twitch torque rose to a value almost matching that attained early in the fatigue protocol, then slowly declined. A final example of greater interaction between potentiation and fatigue in type II fibres, was GII’s greater concurrent increase in twitch torque and HRT during the fatigue protocol, reflecting type II fibres’ both greater capacity for potentiation (Moore & Stull 1984, Hamada et al. 2000) and greater susceptibility to fatigue-induced contractile slowing (Dubose et al. 1987, Gordon et al. 1990).

M-wave

Similar to the twitch, there was potentiation of the M-wave during the fatigue protocol. However, unlike the twitch, which showed initial potentiation followed by depression, potentiation of the M-wave increased progressively throughout the fatigue protocol. There was also a difference during recovery. Twitch torque, which had been depressed by the end of the fatigue protocol, increased early in the recovery period before falling to baseline values. In contrast, M-wave amplitude and area steadily declined towards the baseline value from the start of the recovery period.

The little concordance between the changes in the twitch and M-wave suggest that the mechanism for M-wave potentiation is different from that previously described for twitch potentiation (myosin light chain phosphorylation). Potentiation of the M-wave is attributed to activity-induced stimulation of the muscle fibre membrane’s Na⁺–K⁺ pump (McComas et al. 1994). The Na⁺–K⁺ pump causes hyperpolarization, which in turn increases the amplitude of the muscle action potential (Hicks & McComas 1989).

We also observed greater M-wave potentiation in muscles with a higher percentage of type II fibres. This has also been observed in a comparison of different human muscles (Duchateau et al. 1987; cf. Galea 2001). Similarly, greater M-wave potentiation has been observed in the fast, compared with slow, motor units of cat tibialis anterior (Enoka et al. 1992). The cause of the greater potentiation in fast fibres has not been established. In human quadriceps, there is no difference in Na⁺–K⁺ pump concentration in between type I and type II fibres (Dorup et al. 1988). On the contrary, ‘fast’ rat extensor digitorum longus has a greater concentration of Na⁺–K⁺ pumps than ‘slow’ soleus, but this may be offset by the former’s greater concentration of Na⁺ channels (Clausen et al. 1998).

In summary, the present study has shown that muscles with a high percentage of fast, type II fibres exhibit greater post-activation potentiation of twitch torque early in a fatigue protocol but greater fatigue later in the protocol. These muscles also exhibit greater potentiation of the muscle compound action potential (M-wave).

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References