

# Electrical and mechanical responses in the platysma and in the adductor pollicis muscle: in normal subjects

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**SUMMARY** In the platysma of 34 normal subjects the amplitude of the action potential and twitch tension and tetanic tension were lower, the contraction time of the isometric twitch was 1.4 times shorter, and the potentiation of twitch tension in a staircase and after tetanus was two to four times greater than in *m. adductor pollicis*. Differences in twitch kinetics and potentiation were related to the four times higher incidence of fast fibres in the platysma than in the adductor pollicis muscle, as determined by histochemistry. Ninety-five per cent confidence limits were established for comparison with patients with myasthenia gravis.

Recordings of the electrical and mechanical responses in myasthenia gravis have hitherto been confined to the intrinsic muscles of the hand, though muscles of the eyes, face, and neck are involved earlier and more severely. This study describes normal findings, electrical and mechanical responses in the platysma to single and repetitive stimuli, and compares them with those obtained in this laboratory by Slomić *et al.* (1968) in *m. adductor pollicis* (ADP).

## Method

The platysma was chosen because electrical and mechanical responses to indirect stimuli could be recorded without interference from other muscles, and the inertia of the mass of the muscle and of the recording system was small, allowing the time course and tension of the twitch to be recorded with little distortion. To attain reproducible mechanical recordings, the patient's head was positioned between a steel helmet and a metal clamp on the chin (Fig. 1). The helmet and clamp were fixed to a heavy stand behind a chair, adjustable to fit the position of the head.

## STIMULATION

Rectangular current pulses, 0.2 ms in duration, were delivered *via* stainless steel needles, 0.7 mm in diameter with a 3 mm bared tip, to the cervical branch of the

facial nerve behind the angle of the jaw (Fig. 1). The cathode was positioned near the nerve by finding a threshold for evoking the muscle action potential of less than 1 mA. The stimulus strength was increased four to six times (9–20 mA) above the current that elicited a maximal response. Care was taken to ascertain that the stimulus current was maximal throughout the examination.

## RECORDING OF ELECTRICAL RESPONSES

The muscle action potential was recorded *via* stainless steel needles, 0.7 mm in diameter, inserted subcutaneously for a length of 0.5–1 cm, the stigmatic electrode in the end-plate region (6–11 cm from the stimulating cathode) and the remote electrode below the clavicle, 4–15 cm from the stigmatic electrode (Fig. 1). The electrode impedance was diminished (measured in 0.15% saline with a potential difference of 2 mV) by passing an alternating current of 70 mA for 30 seconds through the electrode in saline at 90°C (Buchthal and Rosenfalck, 1966). The impedance was about 1000  $\Omega$  for 20–10 000 Hz. An earth-electrode was placed between the stimulating and recording electrodes. The pick-up of the remote electrode was less than 1% of the potential recorded by the stigmatic electrode, seen from recordings between the remote and another still more remote electrode placed on the contralateral shoulder (Fig. 2). The muscle action potential was amplified by an amplifier with a frequency band of 20 Hz–10 kHz, 3 dB down (DISA, 9014C0101).

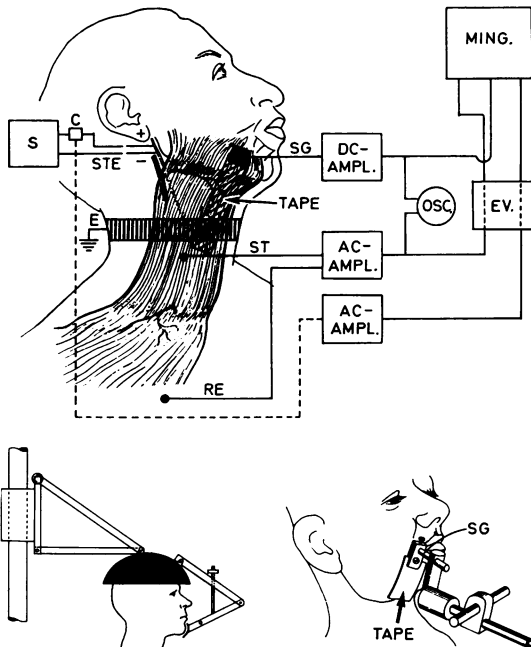


Fig. 1 Apparatus for recording electrical and mechanical responses in the platysma. Below left: fixation of the head between a helmet and a cup on the chin. Above: S—stimulator; STE—stimulating electrodes placed along and near the cervical branch of the facial nerve. The stimulating current was recorded via a transformer, C, on one channel of the event recorder (EV.) and the ink writer (MING.). ST—stigmatic electrode and RE—remote electrode to record the muscle action potentials via the event recorder (EV.) on an ink writer (MING.). The tension of the muscle was measured by a strain gauge, SG (see below right), via inextensible tape and recorded on one channel of the ink writer.

#### RECORDING OF MECHANICAL RESPONSES

The tension was measured by a strain gauge (Buchthal and Schmalbruch, 1970) placed on the clamp that kept the chin in position (Fig. 1), via almost inextensible tape<sup>1</sup> (2 cm wide, 7–10 cm long) placed on the skin over the muscle (Fig. 1). The strain gauge was calibrated before and after each examination. The resting load (100–200 g) was adjusted such that the force during contraction was maximal.

#### STATIC AND DYNAMIC PROPERTIES

A force of less than 1000 g was recorded without distortion; 1000–1500 g were measured 5–10% too small. The total tension was at most 1300 g. A step-change in length applied *in situ* was critically damped. The rise time of 3 ms to 90% of the peak of the step-

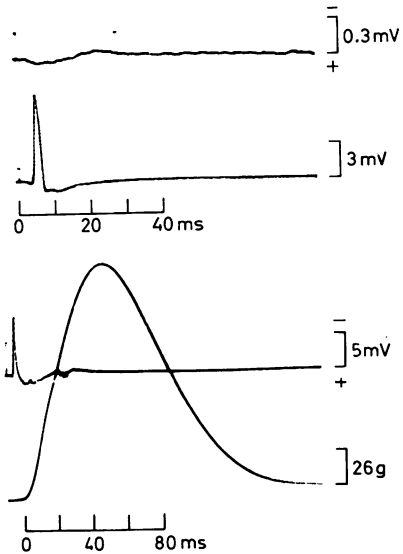


Fig. 2 Above, lower trace: action potential recorded in the end plate region; upper trace: potential recorded between the remote and another still more remote electrode on the contralateral shoulder. Below, upper trace: action potential recorded in the end plate region; lower trace: the isometric twitch.

change was suitable, as the contraction time of the twitch was 35–70 ms (Fig. 2).

The tension was recorded almost isometrically; at a load of 1000 g the tape that connected the muscle to the strain gauge was stretched at most 10%, and did not yield below a load of 2000 g.

#### DISPLAY OF RECORDINGS

The time base to record the parameters of the responses was 0.25 ms/mm for the latency of the action potential, 0.5 ms/mm for the latency of the twitch, and 2 ms/mm for the contraction time and the relaxation time. Electrical and mechanical responses and the stimulus current were recorded on a 3-channel electromyograph (DISA, 9014B0701), and on a dual beam storage oscilloscope (Tektronix 564), or on an ink jet-writer with an upper limiting frequency of 1000 Hz (Mingograph, Siemens). The twitch tension was recorded directly, the action potential and the stimulus current by an 'event-recorder' (1000 points, 8 bit) that converted the frequency range from 20–10 000 Hz to 2–1000 Hz (Dahl and Buchthal, unpublished).

#### HISTOCHEMISTRY

Biopsies of the platysma were taken from three males undergoing carotid endarterectomy and who had no symptoms or signs of neuromuscular disease. The

incidence of fibre types was determined by staining for lactic dehydrogenase and by counterstaining for alpha-glycerophosphate dehydrogenase, and fibres were typed according to Nachmias and Padykula (1958). There were three types, C fibres (rich in mitochondrial and poor in glycolytic enzymes), B fibres (intermediate content of mitochondrial and rich in glycolytic enzymes), and A fibres (poor in mitochondrial and rich in glycolytic enzymes). C fibres correspond to type I fibres (slow fibres, poor in adenosine triphosphatase, ATPase, at pH 9.4) and A and B fibres to type IIB and IIA fibres (fast fibres, rich in ATPase at pH 9.4; Brooke and Kaiser, 1970).

#### TEMPERATURE CONTROL

The temperature on the skin over the platysma was kept at 36°C by an automatically controlled infra-red heating element.

#### STATISTICAL EVALUATION

Limits of significance were evaluated by the *t*-test or from cumulative distribution curves (Croxtton, 1959).

#### PROGRAMME OF STIMULATION

1. Single supramaximal stimuli to determine the time course of electrical and mechanical responses.

2. Trains of stimuli delivered at a rate of 2, 3, 5, 10s<sup>-1</sup> for 1.5–3 seconds with 1–2 minutes between trains.

3. Trains of 1 and 2s<sup>-1</sup> (platysma) and 2s<sup>-1</sup> (ADP) for 90 seconds to elicit the staircase phenomenon. After the staircase, single stimuli were given once every half minute for two minutes, and then once every minute for four minutes to ascertain when responses reached resting levels.

4. Tetanic stimuli (20 and 50s<sup>-1</sup> for 1.5 seconds), followed by single stimuli after two, five, 10, 20, 30, 40, 50, and 60 seconds to record post-tetanic facilitation of the action potential and post-tetanic potentiation of twitch tension. Post-tetanic exhaustion (Desmedt, 1966) was evaluated from 3s<sup>-1</sup> trains of stimuli 1.5 seconds in duration, given two, three, four, five, and six minutes after the tetanus.

5. The position of the stimulating cathode was checked by redetermining the threshold current and

the current required to elicit a maximal response.

#### Normal subjects

Thirty-four subjects, eight females and 26 males, 20–59 years of age, without history, symptoms or signs of neuromuscular disease were examined.

#### Results

##### HISTOCHEMISTRY

The mean diameter of 3549 fibres from three platysma muscles was 45 μm (SD: 16 μm), 25% smaller than (*P* < 0.001), and with a larger scatter than in m. biceps brachii (biopsies from four normal males, 2173 fibres, mean: 60 μm, SD: 10 μm, Kamieniecka, personal communication). The average diameter of type A fibres was 10–20% larger than (*P* < 0.001) that of B and C fibres. The incidence of the number of fibres of different type in the platysma is shown in Table 1.

##### SINGLE STIMULI AND SHORT TRAINS OF STIMULI

In the platysma the amplitude of the action potential, of the twitch tension (*P*) and of the tetanic tension (*P*<sub>0</sub>) were lower, the twitch:tetanus ratio (*P*/*P*<sub>0</sub>) was greater, the contraction time (CT) was shorter and the rate of relative force development (in units of tetanic tension, *P*/*P*<sub>0</sub>/CT) was faster than in the ADP (Table 2).

Even in normal muscle there may be a small decrement in the size of the action potentials and the mechanical responses during repetitive stimulation (Fig. 3). The decrement was similar in the platysma and the ADP, and was less in the electrical than in the mechanical response. The scatter of values from subject to subject was small, the lower 95% confidence limit for the action potential was –5–10%, for the twitch tension –15–25% below at a stimulus frequency of 5s<sup>-1</sup>. At 50s<sup>-1</sup> the variation was large, the 95% lower confidence limit being –40%.

##### POST-TETANIC CHANGES

The amplitude of the action potential remained constant after the tetanus in the platysma and in the ADP, whereas the increase in twitch tension (post-tetanic potentiation, PTP) was three to four times greater in the platysma than in the ADP (+85 ± 8% compared with +27 ± 4%, mean ± m.e., *P* < 0.01, Figs. 3 and 4). In both muscles pretetanic tension was attained six to ten minutes after the tetanus. Post-tetanic exhaustion did not occur in the platysma, but was present in two subjects in the ADP.

In both muscles the contraction time was the same in the potentiated twitch as in the twitch before the tetanus.

Table 1 *Fibre types in platysma\**

|                                  | Type |              |      |
|----------------------------------|------|--------------|------|
|                                  | A    | B            | C    |
| Content of mitochondrial enzymes | Poor | Intermediate | Rich |
| Number of fibres (total 3549)    | 2075 | 731          | 743  |
| Incidence of fibre types (%)     | 58   | 21           | 21   |
| Standard deviation (%)           | 8    | 8            | 4    |

\*Determined by lactic dehydrogenase and counterstained by alpha-glycerophosphate dehydrogenase.

Table 2 Responses to single and tetanic stimuli

|   | Platysma |       |     | <i>M. Adductor pollicis</i> |      |     |
|---|----------|-------|-----|-----------------------------|------|-----|
|   | <i>n</i> | Mean  | SD% | <i>n</i>                    | Mean | SD% |
| <b>Electrical response</b>                        |          |       |     |                             |      |     |
| Amplitude of negative phase (mV)                  | 28       | 5.3†  | 38  | 30                          | 8.0  | 41  |
| Amplitude of peak-to-peak (mV)                    | 27       | 6.3‡  | 41  | 30                          | 14.3 | 39  |
| Latency of muscle action potential (ms)           | 29       | 3.2   | 17  | 30                          | 2.8  | 11  |
| <b>Mechanical response</b>                        |          |       |     |                             |      |     |
| Twitch tension (P in g)                           | 34       | 99‡   | 32  | 30                          | 470  | 52  |
| Contraction time (CT in ms)                       | 34       | 48‡   | 11  | 29                          | 65   | 11  |
| Relaxation time (ms)                              | 34       | 40§   | 11  | 29                          | 82§  | 13  |
| Latency of the twitch (ms)                        | 34       | 7.6   | 14  | 29                          | 8.8  | 13  |
| Rate relat. force develop. (P/P <sub>0</sub> /CT) | 31       | 2.8‡  | 26  | 23                          | 1.4  | 36  |
| Twitch: tetanus ratio (P/P <sub>0</sub> )         | 31       | 0.13‡ | 25  | 23                          | 0.09 | 32  |
| Tetanic tension (P <sub>0</sub> in g)             | 31       | 707‡  | 28  | 23                          | 4570 | 25  |

*n*: number of subjects.

SD%: the SD from subject to subject in per cent of the mean.

§Half relaxation time measured in the platysma, three-fourth relaxation time in the ADP.

‡Statistical differences: \**P* < 0.05, †*P* < 0.01, ‡*P* < 0.001 from subject to subject in the platysma and the ADP.

Normal values in the ADP from Sloimic *et al.* (1968).

The SD, within the subject, of the amplitude of the action potential and the twitch tension was 8% and 13% in the platysma and 2% and 8% in the ADP; of the contraction time it was 4%.

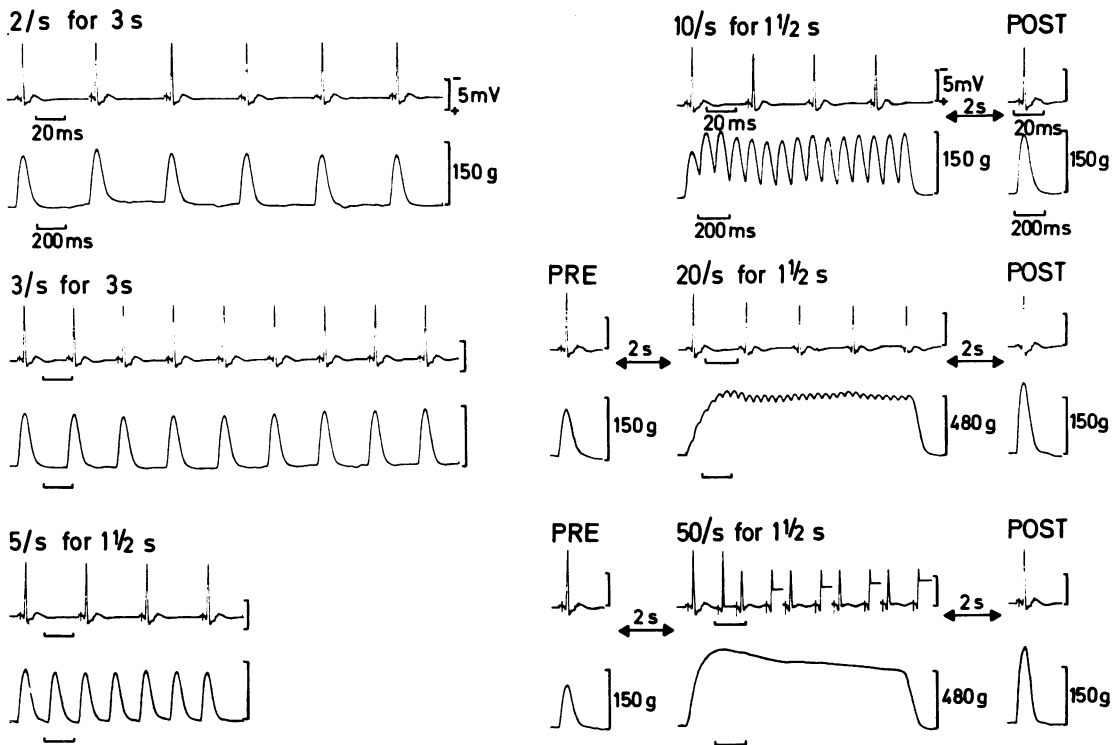


Fig. 3 Electrical (upper traces) and mechanical (lower traces) responses of the platysma to short trains of stimuli of different frequency. Right: PRE indicates the response to a single stimulus before tetanus, and POST the response to a single stimulus given two seconds after tetanus. Note the increase in twitch tension after tetanus (post-tetanic potentiation). Thirty five year old man without history, symptoms, or signs of neuromuscular disease.

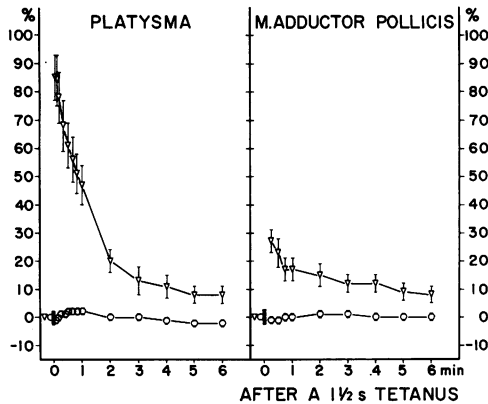


Fig. 4 Post-tetanic potentiation in the platysma and the ADP as a function of time after a tetanus (50 stimuli per second for 1.5 seconds, 1 end of tetanus) in per cent of the pretetanic responses.  $\nabla$  twitch tension.  $\circ$  action potential. The vertical bars denote the mean error. Data from the ADP are taken from Slomić *et al.* (1968).

STAIRCASE PHENOMENON

The amplitude of the action potential remained unchanged in the platysma and in the ADP (Fig. 6).

At a stimulus frequency of  $2s^{-1}$  the staircase was twice as large in the platysma as in the ADP ( $+88 \pm 9\%$  compared with  $+42 \pm 5\%$ , mean  $\pm$  m.e.,  $P < 0.01$ , Fig. 6). Maximum potentiation reached peak at 40 seconds in the platysma as compared with 90 seconds in the ADP. In the platysma the staircase increased with increasing frequency of stimulus (Fig. 5), it was

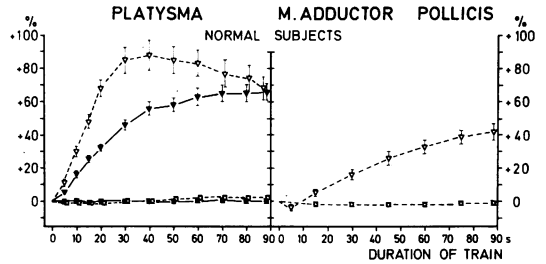


Fig. 6 Percentage increase in twitch tension ( $\nabla$ ,  $\blacktriangledown$ ) during a staircase in the platysma ( $2s^{-1}$ , open symbols and  $1s^{-1}$ , solid symbols) and in the ADP ( $2s^{-1}$ ).  $\circ$ ,  $\bullet$ : action potential. The vertical bars denote the mean error. Data from the ADP are taken from Slomić *et al.* (1968).

$25\%$  larger when 80 stimuli were given at  $2s^{-1}$  than at  $1s^{-1}$  ( $P < 0.05$ , Fig. 6), whereas it depended on the number of stimuli rather than on the frequency in the ADP (Slomić *et al.*, 1968). With a stimulus frequency of  $2s^{-1}$  in the platysma but not in the ADP, the twitch decreased again after potentiation was maximal (Figs. 5 and 6). During the staircase the contraction time remained unchanged in the platysma, whereas it decreased by  $10\%$  in the ADP. The relaxation time decreased by  $10\%$  ( $P < 0.05$ ) in the platysma and in the ADP, when potentiation was maximal.

POSTSTAIRCASE RESPONSES IN PLATYSMA

After the  $1$  and  $2s^{-1}$  staircases for 90 seconds the action potential remained unchanged (Figs. 5 and 7). Although potentiation at the end of the staircases of

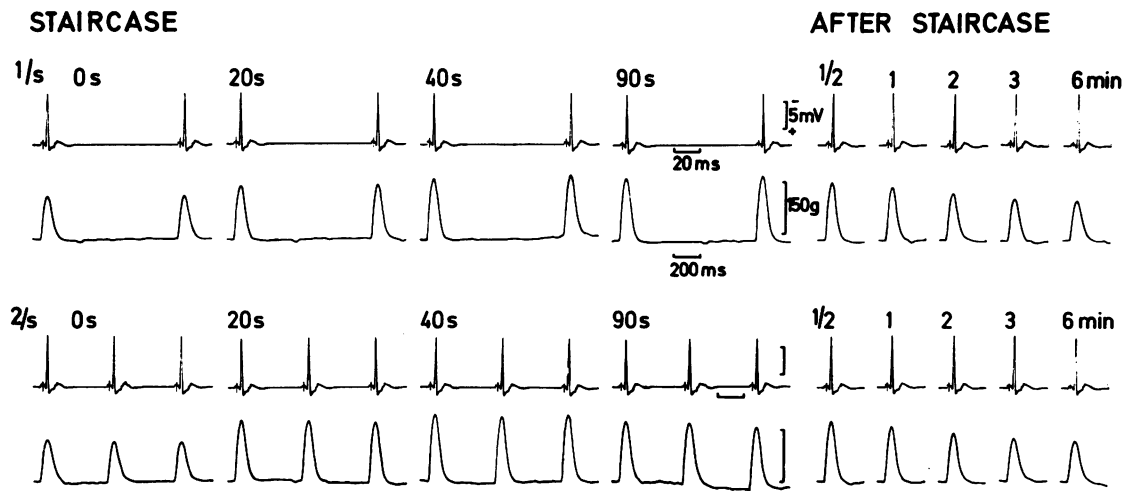


Fig. 5 Electrical (upper traces) and mechanical (lower traces) responses in the platysma during and after a staircase of 90 seconds (above,  $1s^{-1}$ ; below,  $2s^{-1}$ ). Thirty-five year old man without history, symptoms, or signs of neuromuscular disease.

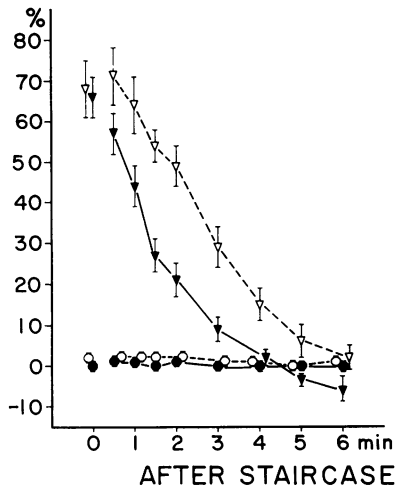


Fig. 7 Increase in twitch tension ( $\nabla$ ,  $\blacktriangledown$ ) as a function of time after the staircase. Time zero denotes the end of the staircase. After  $2s^{-1}$  staircase for 90 seconds, open symbols and after  $1s^{-1}$  staircase for 90 seconds, solid symbols.  $\circ$ ,  $\bullet$ : action potential. The vertical bars denote the mean error.

both frequencies was the same (Fig. 7), the twitch was 15% more potentiated half a minute after the  $2s^{-1}$  than the  $1s^{-1}$  staircase (Fig. 7). Resting levels were attained at both frequencies six minutes after the staircase (Figs. 5 and 7).

## Discussion

The main advantage in recording from the platysma was that electrical and mechanical responses could be recorded from a proximal muscle without interference from other muscles when needle electrodes with a 3 mm bared tip were used to stimulate the nerve.

For anatomical reasons rigid fixation of the platysma was more difficult than of the ADP, reflected in the larger scatter of amplitudes of electrical and mechanical responses in the same patient (Table 2). The variation in amplitude during trains of stimuli was the same as in the ADP and was smaller in the electrical than in the mechanical responses. The variation was small during slow rates of stimuli, but increased above  $5s^{-1}$ . At  $50s^{-1}$  a decrease in the action potential and the mechanical response of about 40% because of movement artefact was within limits of normal.

The contraction time of the whole platysma was as short as that of small bundles of the muscle (Buchthal and Schmalbruch, 1970), consistent with the large proportion of fast fibres in the muscle (80% type II

fibres). Conversely, the ADP had a 40% longer contraction time and contained only 20% of fibres of type II (fast fibres, Johnson *et al.*, 1973).

The difference in incidence of fibre types is also consistent with the greater potentiation of twitch tension in the platysma than in the ADP, since potentiation is confined to fast twitch fibres (Close and Hoh (1968) and Hanson (1974) in rat muscle; Bagust *et al.* (1974) in cat muscle).

Opinions differ as to the mechanism of potentiation of twitch tension: Ritchie and Wilkie (1955) measured a prolongation of the active state in PTP in frog muscle at  $0^{\circ}C$ ; Desmedt and Hainaut (1968) believed it to be caused by intensification of the active state, in that the contraction time was shortened in the potentiated twitch of the ADP. The shortened contraction time seems to be a poor gauge of intensification of the active state, as it remained unchanged in the much more potentiated platysma. Similarly, large potentiation was associated with slight or no changes in contraction time in single muscle fibres of frog (Colomo and Rocchi, 1965), and in rat muscle (Close and Hoh, 1968). Rosenfalck (1974) calculated the active state to be intensified during potentiation of the twitch, and more so in the platysma than in the ADP.

Unlike findings in the ADP, the staircase phenomenon in the platysma increased with the frequency of stimulation rather than with the number of stimuli.

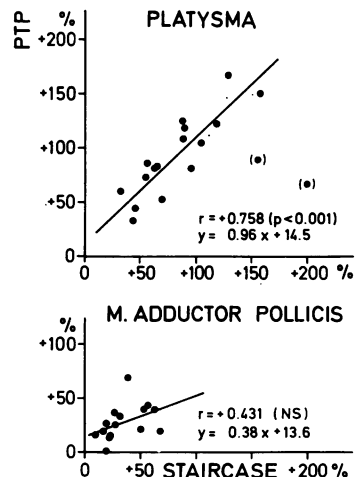


Fig. 8 Maximal post-tetanic potentiation (PTP, ordinate) as a function of the maximal potentiation of twitch tension in a staircase ( $2s^{-1}$ , abscissa) in normal subjects. Symbols in parentheses were included in the calculation of the correlation coefficient but omitted in the calculation of the equation of the relation. In the ADP the relation was not significant (NS).

Similarly, twitch potentiation was 20% larger ( $P < 0.05$ ) two seconds after 30 stimuli delivered at a rate of  $20\text{s}^{-1}$  (PTP), than in a staircase of  $2\text{s}^{-1}$  after 30 stimuli. On the other hand, potentiation was the same when 80 stimuli were given in a staircase ( $2\text{s}^{-1}$ ) as two seconds after a tetanus of  $50\text{s}^{-1}$  (80 stimuli), suggesting that potentiation had reached maximum under both conditions.

Maximum potentiation differed in different subjects, but in the platysma it was the same after a tetanus as during a staircase, suggesting that the mechanism of potentiation was the same under both conditions (Fig. 8).

In the platysma and in the ADP, the action potential remained unchanged after tetanus, presumably because all fibres were activated by supramaximal stimuli. In only one normal subject was there a slight transient block in the action potential after tetanus.

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