Fatigue paradox in the elderly

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Ageing is characterized by a sequence of events leading to a functional reduction of a chain of systems. Among the various tissues and organs affected by this process skeletal muscle undergoes functional and structural changes (Larsson 1978) that are likely to influence the quality of life of the individual. This study was therefore conducted with the aim of investigating the extent and onset of the changes of human skeletal muscle function induced by the process of ageing.

Experimental methods

Both voluntary and electrically evoked isometric contractions of the adductor pollicis muscle (AP) were studied in seventy healthy male subjects aged 20-91yr, 10 for each decade. After warming of the hand and forearm in hot water (≥40°C) for 5 min, maximum isometric voluntary contraction (MVC) of the AP was measured and the highest value out of three trials was chosen. Electrical stimulation of the AP was carried out at the wrist with supramaximal 50 μs square-wave impulses as described by Edwards et al. (1977). The frequency-force relationship was determined by a train of impulses at 1, 10, 20, 30 and 50 Hz for 2 s each and expressing force values as the percentage of the force at 50 Hz. Maximum relaxation rate (MRR) was measured from the differential of the force signal after stimulation of the muscle for 1 s at 30 Hz and was expressed as the percent decrease in force over 10 ms. Isometric endurance was assessed during a 30-s stimulation at 30 Hz and was defined as the percentage of the final force over the initial force.

Statistics.
ANOVA was used to determine wether the age factor had any significant effect on MVC, frequency-force relationship, MRR and endurance. To locate differences between means the Tukey test of critical differences was applied, significance was set at the 5% level. All data are reported as means±SE.

Results

Isometric MVC was quite well mantained up the age of 59 yr but thereafter showed a significant decline ($p < 0.001$ - 0.05, Tukey test) and by the eight decade had dropped to 42.4% of its original (2nd decade) value (Fig 1). The 10/50, 20/50 and 30/50 Hz force ratios of the age group > 80 yr were significantly higher than those of the 20-29 and 30-39 yr groups ($p < 0.05$ - 0.001). A shift to the left of the frequency/force relationship was observed in the oldest age group (Fig 2) and fusion was virtually complete at 30 Hz as compared to 50 Hz in the two youngest groups (20-29 and 30-39 yr). MRR similarly to MVC, did not show any significant deterioration prior to the age of 59 yr after which the rate of decline became significantly faster ($p < 0.05$ - 0.001). From the second to the eight decade it decreased by of 48.7% (Fig 3). Isometric endurance showed a paradoxical, linear increase with age ($p < 0.001$, Fig 4) and from the second to the eigth decade the increase was of 25.5%.

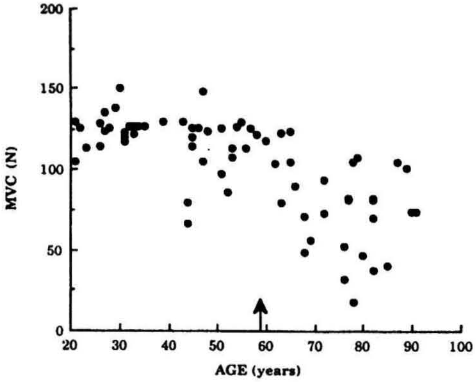

Figure 1. Individual values of maximum voluntary contraction (MVC) force from 20 to 91 yr. Arrow, age after which changes in MVC become significant (Tukey test).

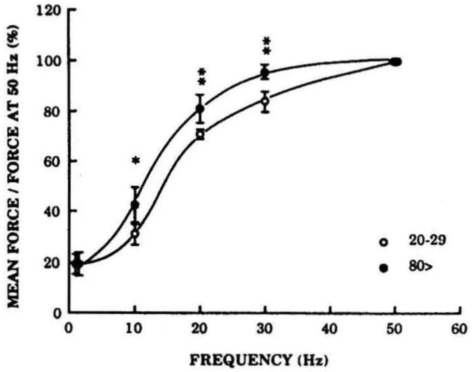

Figure 2. Frequency-force curves for youngest (20-29 yr) and eldest (>80 yr) groups (means ±SE). Group from 30 to 39 yr not shown, because it was not statistically different from 20- to 29-yr group. Significance of Tukey test: * $P < 0.05$; ** $P < 0.001$

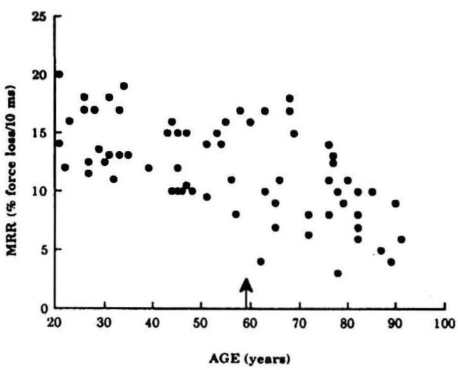

Figure 3. Individual values of maximum relaxation rate (MRR) from 20 to 91 yr. Arrow, age after which changes in MRR become significant (Tukey test).

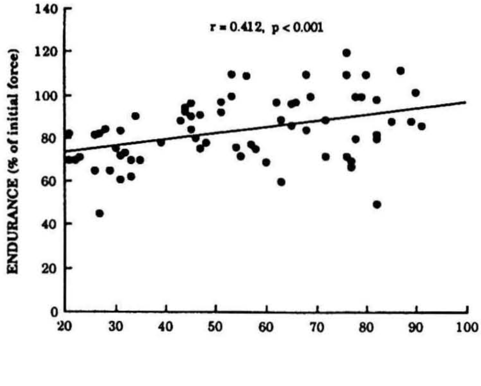

Figure 4. Individual values of isometric endurance from 20 to 91 yr. Correletion coefficient (r) and probability (P) refer to fit of data points in linear regression equation.

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Discussion

These findings show that with ageing skeletal muscle becomes weaker, slower, is tetanized at lower fusion frequencies but appears paradoxically more resistant to static fatigue. These changes are probably related to structural alterations of the neuro-muscular system. Muscle atrophy for instance, which may originate from progressive disuse and from the denervation of motor units following axonal degeneration, is probably one of the main causes for the decrease in MVC. This process however, seems to affect type II fibres to a greater extent and leads to a proportionate increase in the relative composition of type I fibres. As these fibres have lower fusion frequencies than type II fibres, an increase in their proportion may concur to the left shift of the force/frequency curve. This effect may also be related to the longer relaxation times of type I fibres than those of type II. An increase in relaxation time would lead not only to a decrease in MRR but also to tetanization at lower frequencies. The reinnervation process of denervated type II fibres by sprouting axons of motor neurons of slow-twitch motor units (Gardiner et al. 1987) and damage to the sarcoplasmic reticulum may also account for the slowing down of muscle (Klitgaard et al. 1989). The paradoxical increase in isometric endurance may be consequential to the relative increase in the proportion of the more fatigue-resistant type I fibres but may also be related to the force potentiation resulting from the slower relaxation. It may be thus concluded that with ageing, despite the decrease in force, the slowing down of muscle and loss of anaerobic muscle fibres may act as "preservation mechanisms" for the maintenance of force during prolongued, static contractions.

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