Fatigue and recovery of voluntary and electrically elicited dynamic force during cycling exercise in humans

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Studies using electrical stimulation have shown that subjects are usually able to fully activate the quadriceps muscles in an isometric contraction including under conditions of fatigue (Bigland-Ritchie et al, 1978). It was not known whether this was also true for the main knee extensor muscles during maximal dynamic exercise involving a complex multi-joint movement as in cycling.

Methods

-*Force recording* : Force measurements were made during cycling on an isokinetic cycle ergometer in which the cranks were driven by an electric motor with a constant pedal frequency of 60 rev/min. Forces exerted on the pedals were monitored by strain gauges in the pedals.
-*Electrical stimulation* : During cycling the quadriceps muscles were stimulated transcutaneously through two 5 x 20 cm aluminium foil electrodes. The electrodes were applied proximally and distally on the anterior aspect of the thigh. Square wave pulses of 50μs duration were used at 200V. A train of 4 stimuli at 100Hz was delivered during 50ms. Stimulation of the resting quadriceps muscles in an isometric situation generated forces that were 36 ± 9% of the isometric MVC at the same knee angle.
-*Protocol*: : Fatigue was induced in 7 male subjects by a maximal sprint effort lasting 25s. Fatiguing exercise was performed on the iso-kinetic cycle ergometer at a pedal frequency of 60 rev/min. Before and after the sprint subjects allowed their legs to be passively taken round by the motor. During this passive movement the quadriceps were stimulated in order to generate peak stimulated force at 90° past top dead centre. The moment of stimulation was chosen such that peak stimulated force occurred at the same knee angle as the maximal voluntary force during maximal cycling exercise (Note this is a slightly different angle compared to the passive situation).

Forces generated by electrical stimulation of the passive muscle were determined before, and at intervals during the 20 minute recovery after the sprint. Measurements were made of the peak force and the maximum rate of force development as shown in figure 1.

Recovery of voluntary force was assessed in 4 subjects in a series of separate experiments in which, after recovery periods of different durations,.subjects performed a second maximal sprint effort

Results and Discussion

Peak stimulated force (PSF) immediately after the sprint was reduced to 69±3% (Mean ±SD). After 3 minutes recovery peak PSF had returned to pre-sprint values (97±5% of control). After about 5 minutes PSF reached 10% higher values compared to control. Thereafter stimulated force returned to control values (figure 2). The rate of force development was also reduced following the fatigue to 65±8% of control and recovered with a similar time course as the peak stimulated force.

Voluntary force was reduced to 75 ± 5% of the control value at the end of the sprint but had fully recovered after 3 minutes (98±3% of control).

The association between the changes in stimulated force and voluntary force suggests that the fatigue in this type of dynamic exercise may be due to changes in the muscle itself and not to failure of central drive.

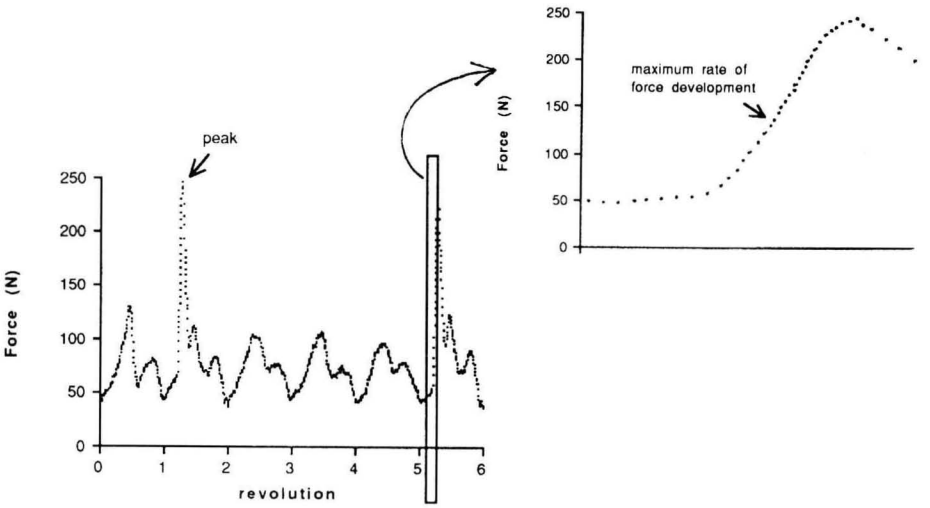

Figure 1. Example of force recording. Peak stimulated force and maximum rate of force development were calculated.

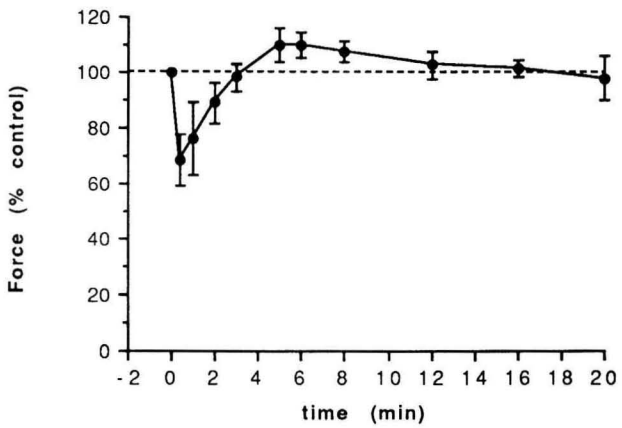

Figure 2.Peak stimulated force (expressed as % of control) before and at intervals during the recovery after the maximum sprint effort. Mean and SD of 7 subjects are given.

Reference

Bigland-Ritchie, B., Jones, D.A., Hosking, G.P., and Edwards, R.H.T. (1978) Central and peripheral fatigue in sustained voluntary contractions of human quadriceps muscle. *Clinical Science.* **54**, 609-614.