Effect of contraction velocity on the pattern of glycogen depletion in human muscle fibre types

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The pattern of glycogen depletion in histochemically typed muscle fibres has been used to investigate recruitment patterns during cycling exercise in humans (e.g. Gollnick et al.1974, Vøllestad et al.1984). These studies showed a sequential depletion of glycogen in type I, IIA and IIB fibres with increasing exercise intensity and/or duration. In these studies most experiments were conducted at a relatively low pedalling rate of 60-70 rev/min . Although in the early study of Gollnick et al the authors reported that an increased pedalling rate did not demonstrably alter the glycogen depletion pattern there are no other reports to our knowledge which have examined this aspect. This is surprising since it might be expected that the proportional contribution to mechanical power output from different human muscle fibre types would vary with contraction velocity (see Sargeant and Beelen, 1993), and further that this would be associated with changes in energy turnover and glycogen depletion. Such an effect would have implications for the development of selective fatigue of fibre type populations as we have previously speculated (Beelen and Sargeant 1991, 1992)

The present study therefore examines the effect of different pedalling rates on the pattern of glycogen depletion in different muscle fibre types during cycling exercise.

Methods

Four subjects performed 2 experiments at pedalling rates of 60 and 120 rev/min on a bicycle ergometer (Lode, the Netherlands). Each experiment consisted of 2 periods of 6 min at 90% VO_2max with 10 min unloaded cycling in between. The exercise was preceded by a warm up period at a power output requiring ~30% VO_2max. Pedal frequency was randomly selected: 60 or 120 rev/min. After at least 4 days the exercise protocol was repeated using the alternative pedalling rate.

During exercise heart rate was continuously monitored. Expired air was collected during the last two minutes of each 6 min exercise bout and analysed for O_2 and CO_2. Blood samples were taken from the finger tip immediately after exercise and analysed for lactate concentration.

Muscle biopsies (UCH needle, 4mm) were taken from the vastus lateralis muscle before and immediately after exercise. From each muscle sample serial cross sections (10μm) were cut. For identification of muscle fibres, sections were stained for myofibrillar ATP-ase. Muscle fibres were classified as type I, IIA or IIB fibres. In order to estimate glycogen content of the individual fibres sections were stained using the periodic acid Schiff (PAS) reaction. The optical density of the PAS-stain was determined photometrically.

Paired t-tests were used to compare heart rate, VO_2, respiratory exchange ratio and blood lactate concentration between the two experiments. Differences between the reduction in optical density of glycogen stain after exercise at 60 and at 120 rev/min were tested using analysis of covariance (Kleinbaum et al. 1988).The significance level was set at 5%.

Results

The experiments were matched for relative intensity expressed as $\%VO_2max$. Since the VO_2max was not different at 60 and 120 rev/min both relative and absolute exercise intensity were the same in both experiments. Respiratory exchange ratio, heart rate and blood lactate values were also similar (Table 1).

The optical density of the PAS-stain was significantly reduced after exercise (at 60 and 120 rev/min) in all fibre types. In comparing the effect of exercise performed at 60 and at 120 rev/min it must be realised that mechanical power output was significantly less when pedalling at 120 rev/min by 80 ± 16W. The absolute peak force exerted in each revolution was also less at 120 rev/min. Furthermore even if this force were expressed as a percentage of the maximum force available at the same velocity of pedalling it would also be less than at 60 rev/min (Sargeant, 1988).

Despite the similarity of VO_2 and a lower mechanical power output at 120 rev/min there was significant greater glycogen depletion in type IIB fibres at the faster pedalling rate (Table 2). Also in type I and 11A fibres the reduction tended to be greater after exercise at 120 compared with 60 rev/min.

	60 rev/min	120 rev/min
% of VO_2max	92 (9)	92 (3)
VO_2 (l/min)	3.5 (0.4)	3.6 (0.5)
HR (beats/min)	168 (13)	175 (11)
RER	1.07 (.06)	1.04 (.06)
BLa (mM)	8.2 (2.5)	7.6 (1.3)
Power Output (W)	279 (53)	198 (50)

Table 1. Mean (SD) values of the actual measured oxygen uptake (VO_2), heart rate (HR), respiratory exchange ratio (RER) and blood lactate concentrations (BLa) during exercise.

	60 rev/min			120 rev/min		
	I	IIA	IIB	I	IIA	IIB
before exercise	12.4 (1.6)	13.8 (2.2)	11.8 (2.3)	13.0 (0.8)	14.9 (1.5)	12.7 (1.8)
after exercise	9.3 (2.4)	11.2 (3.0)	10.1 (1.8)	7.2 (2.9)	8.9 (3.9)	8.6 (2.0)

Table 2. Mean (SD) values for optical density of glycogen stain of type I, IIA and IIB fibres before and after exercise at 90% VO_2max with a pedalling rate of 60 and 120 rev/min (n=4).

Discussion

We had hypothesised that there would be a relatively greater proportional contribution to the mechanical power output of the whole muscle from type II muscle fibres at the higher pedalling rate. Further we expected that this would be reflected in greater energy turnover and glycogenolysis in those fibres. Insofar as there was a significant greater glycogen depletion in type IIB fibres after exercise at 120 rev/min compared with exercise at 60 rev/min our expectations were confirmed. There was also however a tendency for an increased depletion in type I and IIA fibres and at first sight this is somewhat surprising.

Clearly however these results do not support the conclusion, based on EMG data, of Citterio and Agostoni (1984) that there is a derecruitment of type I fibres at fast pedalling rates.

It must be realised that in comparing exercise performed at 60 with exercise performed at 120 rev/min not only contraction velocity is different but also the number of contractions. Since during exercise at 120 rev/min twice as many contractions are performed than during exercise at 60 rev/min, the (mechanical) start-up costs will be twice that during exercise at 60 rev/min. It does seem possible that although type I fibres are recruited during exercise at 120 rev/min they are operating on the descending arm of a mechanical efficiency/velocity relationship (see Rome 1993; and Sargeant and Beelen 1993). The consequence would be that proportionately more power would need to be generated by the type II fibre populations and together with the increased start-up costs this may lead to an increased glycogenolysis in both type I and type II fibres.

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