**ORIGINAL ARTICLE**

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**A short training programme for the rapid improvement of both aerobic and anaerobic metabolism**

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**Abstract** The aim of this study was to evaluate the changes in aerobic and anaerobic metabolism produced by a newly devised short training programme. Five young male volunteers trained daily for 2 weeks on a cycle ergometer. Sessions consisted of 15-s all-out repetitions with 45-s rest periods, plus 30-s all-out repetitions with 12-min rest periods. The number of repetitions was gradually increased up to a maximum of seven. Biopsy samples of the vastus lateralis muscle were taken before and after training. Performance changes were evaluated by two tests, a 30-s all-out test and a maximal progressive test. Significant increases in phosphocreatine (31%) and glycogen (32%) were found at the end of training. In addition, a significant increase was observed in the muscle activity of creatine kinase (44%), phosphofructokinase (106%), lactate dehydrogenase (45%), 3-hydroxy-acyl-CoA dehydrogenase (60%) and citrate synthase (38%). After training, performance of the 30-s all-out test did not increase significantly, while in the maximal progressive test, the maximum oxygen consumption increased from mean (SD) 57.3 (2.6) ml · min⁻¹ · kg⁻¹ to 63.8 (3.0) ml · min⁻¹ · kg⁻¹, and the maximum load from 300 (11) W to 330 (21) W; all changes were significant. In conclusion, this new protocol, which utilises short durations, high loads and long recovery periods, seems to be an effective programme for improving the enzymatic activities of the energetic pathways in a short period of time.

**Key words** Human skeletal muscle · Oxidative enzymes · Oxygen uptake · Anaerobic performance · Lactate

**Introduction**

Exercise-induced muscle changes can be modulated by the structure of a training programme (Abernethy et al. 1990). An endurance protocol produces major adaptations in aerobic metabolism (via oxidative enzymes, oxygen uptake ($\dot{V}O_2$) and performance of endurance tests (Henriksson 1996), while sprint training increases the concentration of energetic substrates and the activity of anaerobic-metabolism-related enzymes (Thorstensson et al. 1975; Roberts et al. 1982; Cadefau et al. 1990). However, in most cases, the goal of athletic preparation is to improve a subject’s aerobic and anaerobic characteristics. Usually, an initial endurance phase is undertaken, followed by a second phase of high-intensity or sprint training. Training programmes that are capable of increasing aerobic or anaerobic metabolism (with continuous exercise or interval training) are based mainly on periods of at least 6 weeks (Costill et al. 1979; Jacobs et al. 1987), although there are shorter programmes lasting no more than 1 week. Such programmes are usually based on continuous endurance training, which produces some metabolic and haemodynamic changes, but which do not improve performance, increase the maximum oxygen consumption ($\dot{V}O_2\text{max}$) or produce great enzymatic changes (Green et al. 1992; Cadefau et al. 1994; Phillips et al. 1996; Shoemaker et al. 1996).

Often, however, athletes require a training programme in order to achieve fitness in a short period of time, particularly after periods of inactivity due to injury, illness or personal problems, or when it is necessary to make sudden changes in the training schedule. In these cases, cycle ergometer training has several advantages: the lower cost and size of the equipment required, the large number of muscles involved, the easy and
accurate design of loads and rests, indoor practice unaffected by the weather, and compatibility with some upper-limb injuries. However, each sport will require its own specific training.

Taking into account that the more intense the stimuli, the more intense the adaptations (or overtraining when the training protocol exceeds the capability of muscle adaptation), we applied a training programme that was characterised by high loads and daily application, for a 14-day period to produce the biggest response in this short period. The aim of the present study was thus to describe the physiological and biochemical changes produced in aerobic and anaerobic metabolism through a new incremental training programme of “all-out” loads, repeated daily for 2 weeks, and with long recovery periods.

**Methods**

Subjects

Five healthy male student volunteers agreed to take part in this study. Their mean (SD) age, height and body mass were 20.8 (2.9) years, 171 (5) cm and 68.1 (4.2) kg, respectively. All were active, but none were currently participating in a regular training programme. During the study period, all volunteers stopped their normal physical activity (recreational) and only exercised during the training sessions as part of the experiment. Prior to the experiment, the volunteers underwent a medical check-up to ensure that they were fit and healthy.

The experiment was conducted in accordance with the code of ethics of the World Medical Association (Declaration of Helsinki), and approval was given by the Human Experimentation Ethical Committee of the Pi i Sunyer Biomedical Research Institute of Barcelona (Hospital Clinic i Provincial, University of Barcelona). All subjects were informed before recruitment as to the purpose of the study, known risks and possible hazards associated with the experimental protocol, and each gave their written consent to participate.

**Training protocol**

Familiarisation with the equipment, sprint cycling and testing procedures took place prior to the experiment, until we were confident that volunteers would reach all-out effort from a stationary start. The programme involved fourteen training sessions, and subjects trained every day for 2 weeks (Fig. 1). The sessions without warm-up consisted of a number of repetitions of 15-s cycling with 45-s rest-periods, and a number of 30-s all-out cycling repetitions with 12-min rest-periods. The number of repetitions was modified and the total load increased during training. The first three sessions consisted of two bouts of 15-s, and two bouts of 30-s all-out cycling sprints. In the following sessions, the number of 15-s and 30-s bouts was increased by one every two training sessions. The last three sessions consisted of seven bouts of 15-s and seven bouts of 30-s all-out cycling sprints. As in the performance tests, subjects were instructed to remain seated during the cycle sprints in the training period. The flywheel tension was set at 0.075 kg · kg body mass⁻¹, and remained constant for the duration of the training programme. The maximum pedal revolutions reached by each volunteer in every 30-s bout were recorded. All subjects were highly motivated and verbally encouraged during training, and were instructed to cycle with maximum effort in every session. The purpose of this training protocol was to evaluate whether progressively higher loads that cannot be tolerated for long periods are able to elicit a rapid improvement in the metabolic pathways.

**Performance tests**

In order to quantify any training-induced alterations to anaerobic and aerobic capacities, volunteers performed a 30-s all-out test and a maximal progressive test before and after training (1 and 5 days before and after training, respectively, see Fig. 1).

The 30-s all-out test was performed against a constant tension. The flywheel tension was set at 0.075 kg · kg body mass⁻¹, and remained constant for the duration of both the test and the entire training programme. After a gentle warm-up, the subjects were comfortably seated with feet secured to the pedals by toe clips. They were requested to pedal as fast as possible from the start and were encouraged to maintain maximum pedalling speed throughout the 30-s period. A friction-loaded cycle ergometer (Monark model 814E, Valberg, Sweden) interfaced with a microcomputer was used to attain high-frequency logging of the flywheel angular velocity. The flywheel velocity was monitored every 0.5 s and was

![Fig. 1 A Schematic representation of the study procedures. B Design of the sprint-training programme illustrating the distribution of training sessions, test-biopsy sampling and rest days](image-url)