Effects of Physical Conditioning upon the Central and Peripheral Circulatory Responses to Arm Work

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Summary. 10 sedentary young men completed a programme of 4 weeks endurance training involving bi-weekly 30 min sessions of exercise on an arm ergometer at 80% of maximum aerobic power. Maximum oxygen intake increased by 8%, and there was also a 4% increase in the mechanical efficiency of effort. The cardiac output (measured by acetylene rebreathing) increased in both sub-maximum and maximum effort. There was an 8% increase in maximum stroke volume, but no change of maximum heart rate. Strain gauge measurements showed a diversion of blood flow from skin to muscle with training. This adaptation is of value to the athlete only after alternative methods of heat dissipation have developed. The possible application of the arm ergometer to the training of patients with leg injuries is briefly discussed.

Key words: Arm Work — Skin Blood Flow — Muscle Blood Flow — Cardiac Output — Forearm Flow.

Introduction

During maximum exercise, the arterio-venous oxygen difference of athletes and trained subjects is appreciably greater than that of non-athletes and untrained subjects [7, 17, 19, 21]. This may indicate a redistribution of blood flow from the skin to the active muscles in trained, athletic subjects. However, there are other possible explanations. In an athlete it is particularly difficult to be certain how far the observed responses are attributable to training per se, and how far they reflect genetic differences [9], a high level of motivation, and other unusual features of a competitive environment. Accordingly, it was thought of interest to see what changes of cardiac output and of skin and muscle flow were induced as initially sedentary individuals underwent a conditioning programme.

The regimen selected involved biweekly exercise on an arm ergometer. This form of exercise was chosen for several reasons: a) a good training response seemed likely, because disuse atrophy is more marked in the
arms than in the legs of the city-dweller, b) regular arm exercise could have useful clinical application to the restoration of cardio-respiratory fitness in patients with leg injuries [8], and c) there have been few experimental studies of training induced by arm exercise.

Methods

Subjects and Experimental Plan. 12 healthy male subjects aged 20—35 years were recruited for the programme. Of these, 10 completed all requirements, and the remaining 2 dropped out because of "lack of time". With one exception (an active swimmer), none had participated in regular physical exercise for some years. Physical characteristics are summarized in Table 1. The greatest weight loss (2.7 kg over the 1 month of training) occurred in a man who was initially somewhat obese (weight 93.0 kg, height 186.7 cm); some of the thinner subjects showed a small gain of weight (0.7—0.8 kg) during the study.

Preliminary sub-maximal and maximal tests were carried out 1 week prior to the main study, in order to accustom the subjects to our experimental routine and minimise learning effects. 2 initial definitive tests were separated from each other by an interval of 3 days. At the first of these tests, the heart rate, oxygen consumption, and cardiac output were measured at rest and during sub-maximal and maximal work. In the second test, the procedures were similar, but forearm blood-flow was measured in place of cardiac output. Both definitive tests were repeated after completion of the 1 month training schedule.

Exercise Testing. Exercise was performed with the subjects sitting on a Fleisch "ergostat" (Jacquet Ltd., Basle, Switzerland) and operating the short arm cranks at a speed of 60 revolutions per minute. 4 work loads were so selected that each individual reached his maximum oxygen intake at the final load. Each load was sustained for 5 min, and there was a 5 min rest/recovery interval between loads.

The electrocardiogram was recorded throughout (CM₅ leads); expired gas was collected during the 4th min at each load, and oxygen consumption was determined by standard open circuit techniques [22, 23]. The cardiac output was measured by an acetylene rebreathing method during the 5th min of exercise. A venous occlusion cuff was inflated in the 5th sec post exercise, and forearm blood flow was measured over the subsequent 4—5 sec of the rest/recovery interval.

Training Programme. The subjects reported to the laboratory at a constant time on Tuesday and Thursday of each week, and were required to crank the ergometer for 30 min at a load corresponding to 80% of aerobic power.

Cardiac Output Determinations. The technique — a modification of the classical Grollman procedure [10] — has recently been described [25, 26]. In brief, the subject

| Table 1. Physical characteristics of subjects participating in conditioning programme |
|----------------------------------|------|------|------|
| Age (years)                  | 24.6 | 5.3  | 20—35 |
| Height (cm)                  | 175.8| 8.4  | 163.2—189.2 |
| Weight (kg) initial          | 71.1 | 2.9  | 62.1—93.0 |
| Change during conditioning programme (kg) | -0.3 | 1.2  | -2.7—+0.8 |