The Training Stimulus

The Effects of Intensity, Duration and Frequency of Effort on Maximum Aerobic Power Output

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Summary. The effects of various regimes of bicycle ergometer exercise varying in intensity, duration and frequency of effort on directly measured maximum aerobic power ($\dot{V}_O_2$ max) have been studied on 28 healthy male subjects aged 18—38 years.

Analysis of the results showed that the two most important factors in training $\dot{V}_O_2$ max were intensity and duration; these parameters being interdependent. No subject who trained at or below 50% of $\dot{V}_O_2$ max showed an improvement in his maximum aerobic power output. Even at the highest intensities and longest durations of effort the improvement in $\dot{V}_O_2$ max was quite small (1—9 ml/kg/min). The responses to submaximal work mirrored in part these changes: $\dot{V}_O_2$ and $V_E$ for a given work load remained constant whereas cardiac frequency ($f_H$) decreased after training.

It would seem that in order to effect an improvement in $\dot{V}_O_2$ max an individual must be prepared to work at or close to his maximum for prolonged periods of time; even then the improvement may be disappointingly small.

Key words: Exercise — $\dot{V}_O_2$ max — Training.

The physiological responses of man to repeated submaximal and maximal exercise have been extensively reported (see Astrand [1] for general review) but surprisingly little attempt has been made to examine the exact nature of the training stimulus and the most efficient procedure by which it may be elicited. For example, Durnin et al. [8] have shown that improvement of certain standard indices of fitness are brought about by exercise of relatively low intensity but long duration; whilst others [9] claim that the training stimulus must be sufficiently strong to produce a cardiac frequency during work close to the maximum value (i.e. usually $>170$ beats/min). There is also some confusion regarding the definition and component of fitness which improves. This has been recently emphasised in our own studies of repeated daily exercise on the bicycle ergometer [7] where it was shown that although the regimen of work produced profound changes in the cardio-respiratory responses to
exercise there was little or no change in the directly measured maximum aerobic power output ($\dot{V}O_2\text{ max}$).

To our knowledge the only systematic attempt to investigate the effects of intensity, frequency and duration of effort on $\dot{V}O_2\text{ max}$, is that of Shephard [11]. However, his study can be criticised on several points: 1. although Shephard was aware of the problem of habituation, in our view his experimental design did not allow sufficiently for its effect. Our studies would suggest at least 3 occasions of repeated exercise are necessary to overcome the difficulties of habituation [7]. Shephard merely discarded his first days' results; 2. maximum aerobic power was not measured but predicted from cardiac frequency and work output at submaximal levels using the nomogram of Astrand and Rhyming [2]. In our experience this method, particularly if $\dot{V}O_2$ is also predicted as in his case, is also subject to an error of $\pm 18\%$ and certainly we cannot agree with his statement that “... two work predictions can probably be regarded as the equal of one prediction based on the direct measurement of oxygen consumption”.

For these reasons we have attempted to repeat and extend the experiments of Shephard [11] by studying the effects of intensity, duration and frequency of effort, under carefully supervised laboratory conditions and following 2-week period of habituation, on directly measured $\dot{V}O_2\text{ max}$.

**Experimental Design**

To overcome the difficulties of habituation and learning of the task the subjects exercised daily on the bicycle ergometer over a period of 14 days. The subjects’ maximum aerobic power were then determined and they were randomly allotted to one of 27 procedures as shown in Fig. 1. Each subject was required to work at 80 or 50 or 30% of his $\dot{V}O_2\text{ max}$; for 20 or 10 or 5 min; 5 or 3 or 1 occasion per week. One subject acted as a control. Each training session was supervised in the laboratory and was carried out on the bicycle ergometer. The subjects trained for 8 weeks, and then their responses to submaximal and maximal effort were again monitored.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Units</th>
<th>80</th>
<th>50</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intensity</td>
<td>% $\dot{V}O_2\text{ max}$</td>
<td></td>
<td></td>
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<tr>
<td>Duration</td>
<td>Min.</td>
<td>20</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Frequency</td>
<td>Days/Week</td>
<td>5</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
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$n = 27 + 1$ Control.

Fig. 1. Experimental design