PHYSIOLOGICAL ADJUSTMENTS TO INTENSIVE INTERVAL TREADMILL TRAINING

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ABSTRACT

During a one month training period, eight active men, aged 23-35 years, completed sixteen 30 minute sessions of high intensity interval (5 second work bouts at 16.9 km/hr up 20-25% grade alternated with 10 second rest intervals) treadmill work. In this training period, $\dot{V}O_2$, $\dot{V}_E$ and blood lactate in a 10 minute run at 12.9 km/hr on a level treadmill were unchanged but heart rate during this work decreased by an average of 9 beats/min. During a 4 minute interval work effort at the training intensity, blood lactate accumulation decreased by 40.4%. In exhausting work, mean values of $\dot{V}O_2$, $\dot{V}_E$ and blood lactate increased by 6.2%, 8.2% and 31.6% respectively. Maximal heart rate decreased by an average of 4 beats/min. The average work production of the men in the training sessions improved by 64.5% from 28,160 kgm to 43,685 kgm. No significant improvements were observed in either a short sprint or a stair climbing test which assessed the ability to generate mechanical power from alactacid anaerobic sources. It was concluded that the training regime is an effective method of producing a high total work output in competitive athletes and results in improvements in aerobic power, glycolytic capacity and ability to tolerate the short duration interval work encountered in many games.

Library Classification: interval training, aerobic power; anaerobic power; alactacid oxygen debt; lactacid oxygen debt.

Introduction

The studies of Åstrand, Christensen and others (1, 3, 5) have shown that the alternation of work and rest periods permits more work to be done with less accumulation of lactic acid than work done at the same rate continuously. Furthermore if the duration of the work period was limited to 10 seconds it was possible to delay fatigue for much longer than when completing 30 or 60 second work bouts under similar 1:2 work/rest ratios (3).

There are differing opinions (2, 3, 17, 18, 20, 26, 27) regarding the physiological processes that permit this to occur but it seems that the energy required for short work periods is provided by alactic sources that are partially replenished in a short recovery period and then re-utilized in the next work period. In this manner the involvement of the glycolytic pathway is minimised and a high work production can be sustained.

However, if a 10 second work period becomes too intensive an appreciable production of lactic acid can result. Margaria et al (18) have shown that blood lactate levels of 25 mg % above resting values can be produced in a single 10 second run at less than maximum sprinting speed. These levels were substantially reduced when the duration of the same work load was restricted to 5 seconds.

It was therefore considered that an interval training regime involving 5 second work periods would allow intensive work to be undertaken with only limited splitting of glycogen into lactic acid. A 10 second recovery period interspersed between such work periods would allow partial replenishment of the used energy and so permit the work effort to be repeated. Such a regime, popularly termed "wind sprints" or "spurt training," is in common use in sports such as football, hockey and basketball but has not been evaluated physiologically.

It was the purpose of this study to determine the effects of such a training programme on the various components of aerobic and anaerobic power.

Methods

Eight healthy active male subjects whose physical characteristics are given in Table I, agreed to participate in the study.

The men were required to train on a motor driven treadmill four times weekly for four weeks in an air-conditioned laboratory. Each training session consisted of interval work at 16.9 km/hr up a 20% grade alternating 5 second work periods with 10 second rest periods. The men attempted to complete as many work periods as possible in a 30 minute session by adhering to the specified work/rest routine.

TABLE I

Physical Characteristics of Subjects Before (T1) and After (T2) Training

	AGE YR	HEIGHT CM	WEIGHT KG T1	WEIGHT KG T2	BODY FAT PERCENT* T1	BODY FAT PERCENT* T2
Mean	28.1	178.6	75.1	75.3	11.0	10.5
S.D.	4.7	5.0	6.2	6.6	1.4	1.4

*Estimated from skinfold measurements (31)

Those subjects who completed two training sessions without breaking the exercise format continued the training programme at the same speed up a 25% grade. The men recorded weight and rectal temperature before and after each session and an observer counted the number of repetitions completed. Work production was calculated from percent grade, speed of the run, weight of the individual and total performance time.

The men reported to the laboratory for testing on three separate occasions both before and after the period of training. They were requested to refrain from eating during the three hours prior to undertaking the tests.

During the first test session the men underwent a 10 minute submaximal run at 12.9 km/hr (8 mph) on a level treadmill. $\dot{V}O_2$ was determined in the last 3 minutes of the run by collecting expired air with a system consisting of a Collins Triple J respiratory valve, a 7 litre mixing box and a Parkinson-Cowan dry gasmeter. A Beckman microcatheter sampling pump was used to draw expired air samples at a uniform rate from the mixing box into 2 litre rubber sample bags. The samples were analysed for O_2 and CO_2 concentration by the Beckman E_2 oxygen analyser and a Godart Capnograph CO_2 analyser which were previously calibrated with Scholander analysed gases. Heart rate was monitored during the run by means of radiotelemetry and determined from electrocardiograms. A blood sample was drawn from an arm vein 5 minutes after the run and analysed for lactate by the enzymatic method (12).

After a 10 minute recovery period each man performed a multistage treadmill test in which he ran at 11.3 km/hr (7 mph) up an increasing grade that gradually elevated $\dot{V}O_2$, $\dot{V}_E$, R, HR and blood lactate to maximum levels. The grade was increased by 2% at the end of every minute for the first 5 minutes and then by 1% each minute until the subject was unable to continue. Heart rate and blood lactate were determined as for the 10 minute run. $\dot{V}O_2$ values obtained in the last 2 minutes prior to exhaustion were averaged if they were within 150 ml/min of each other (29). Otherwise the highest value for $\dot{V}O_2$ was assumed to be maximal if R exceeded 1.15 (15) and blood lactate concentration was above 80 mg% (1).

During the second test session the men completed a 4 minute interval effort involving 16 repetitions alternating 5 second work periods and 10 second rest periods at the training intensity of 16.9 km/hr up a 20% treadmill grade. A venous blood sample for lactate analysis was taken 5 minutes after the routine.

The third test session included three tests of alactacid anaerobic power. A stairclimbing test devised by Margaria et al (19) involved running up a staircase at maximum speed, two steps (total vertical height 34.5 cm) at a time. The men were permitted a short approach before reaching the first step and then timed between the fourth and sixth steps. Mechanical power (kgm/sec) was calculated from the rate of vertically lifting their body weight.

The ability to accelerate was assessed by a sprint conducted on a gymnasium floor where the men were permitted a 10 metre approach before being timed for 5 metres. The commonly used 36.6 metre (40 yards) dash was also administered. Times were obtained in each of these three tests with a photo-electric timing system.

Differences between pre and post training values were evaluated by t tests for related groups (10).

Results and Discussion

Training

According to Robinson (22) rectal temperatures and sweat rates increase in proportion to the intensity of work. In the present study, values for rectal temperature taken immediately after each session (mean 39.5°C) and weight loss (mean .64 kg/session) indicate that the 30 minute work sessions were more intensive than the 1 hour sessions alternating interval training with strenuous handball or basketball games conducted by Gisolfi and Robinson (13) in a cool environment. In the latter case rectal temperatures increased to a mean of 39.0°C and were accompanied by a mean loss in body weight of .89 kg per session.

After the post-training tests had been completed three subjects (TM, TO, GT) were assessed in terms of their physiological responses to a typical 30 minute training session.

During the eight work periods between 13-15 minutes, the subject's expired air was directed into one meteorological balloon and during the alternate rest periods into another. This procedure was repeated between 28-30 minutes and enabled the average $\dot{V}O_2$ during work and rest to be estimated. Venous blood samples for lactate analysis were taken before the session and after 10, 20 and 30 minutes of activity. Heart rate was determined throughout from electrocardiograms. The results of these experiments are summarised in Figure 1.

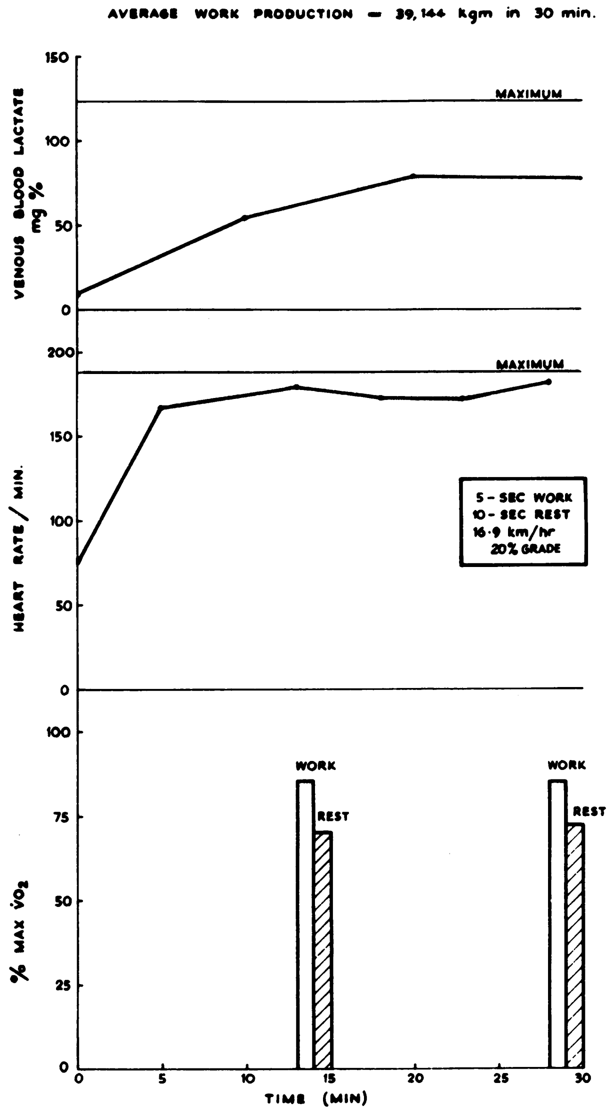

FIGURE 1 MEAN $\dot{V}O_2$, HEART RATE AND VENOUS BLOOD LACTATE OF THREE TRAINED MEN DURING 30-MIN. PERIOD OF INTERVAL TREADMILL WORK.

It can be seen that the men used up to 85% of $\dot{V}O_2$ max. during the work periods and accumulated 75-80 mg% blood lactate near the end of the session. Heart rate remained between 175 and 185 beats/minute for most of the time. The training therefore had both a high aerobic and anaerobic component.

Figure 2 illustrates the ability of the men to adapt to the training load. The average work production in the first 30 minute training session was 28,160 kgm. This increased by 64.5% to 43,685 kgm in the last session. Values of this order have not previously been reported in the literature (3, 20).

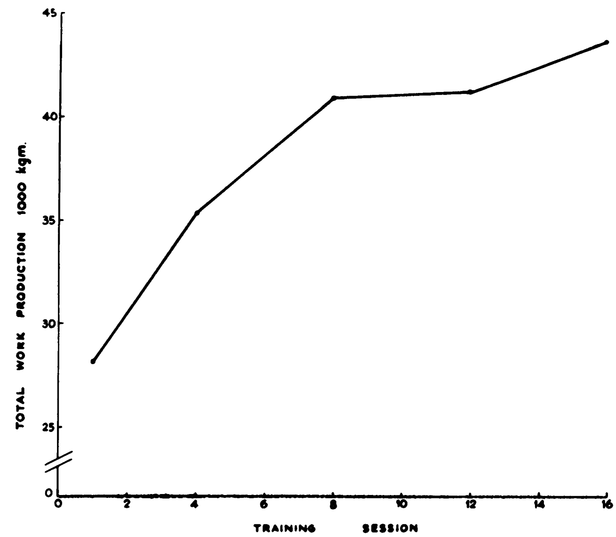

FIGURE 2 MEAN TOTAL WORK PRODUCTION OF EIGHT MEN IN 30 MIN. WORK SESSIONS COMPLETED DURING ONE MONTH OF INTERVAL TREADMILL TRAINING.

In summary it seems that the 5 second work and 10 second rest period format at the treadmill rate and grade specified is an extremely effective method of yielding a high total work output in men of moderate aerobic power experiencing levels of fatigue below the maximum that they can tolerate.

Submaximal Run

Figures 3 and 4 show that there was no change with training in the energy cost of running at 12.9 km/hour on a level treadmill. This was reflected by unaltered $\dot{V}O_2$, $\dot{V}_E$ and blood lactate levels. The 9 beats/minute reduction in heart rate during the run is a well established physiological change (8, 11, 23). The efficiency of these men, as gauged from performance on these variables, is much better than that of the men

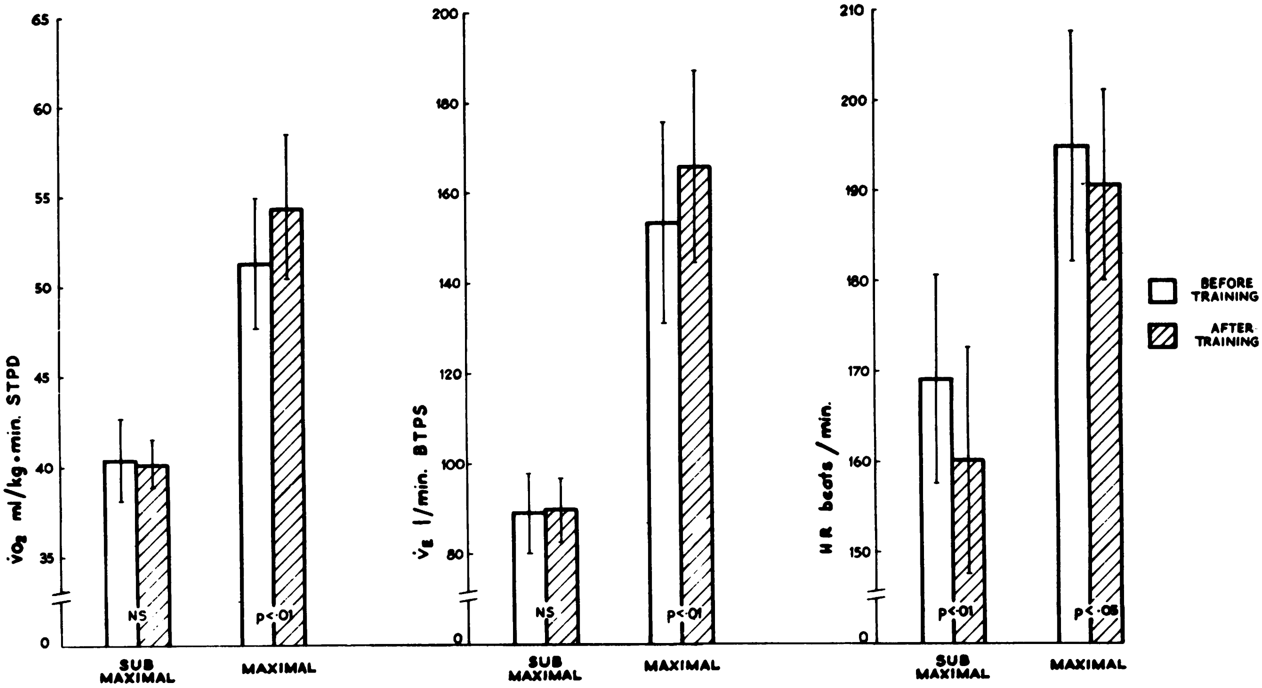

FIGURE 3 EFFECTS OF TRAINING ON $\dot{V}O_2$, $\dot{V}_E$ AND HEART RATE MEASURED DURING SUB MAXIMAL (12·9 km/hr, 0% grade, 10 mins) AND MAXIMAL TREADMILL RUNS.

VALUES GIVEN ARE MEANS. BRACKETS DENOTE S.D.

studied by Robinson and Harmon (25) and pointed to their superior genetic endowment and/or active athletic histories. Before commencing the training programme the men in the present study utilised 78% of $\dot{V}O_2$ max. during the run without producing blood lactate levels much above those normally obtained during rest. Such a minimal anaerobic contribution, probably made during the initial stages of work, was difficult to improve upon. However the subject with the lowest aerobic power succeeded in lowering his blood lactate concentration resulting from the submaximal run, from 49 to 23 mg%. On the other hand, the men of Robinson and Harmon (25) utilised 93% of VO_2 max. and accumulated 76 mg% blood lactate prior to training; a value that was progressively lowered during the training period.

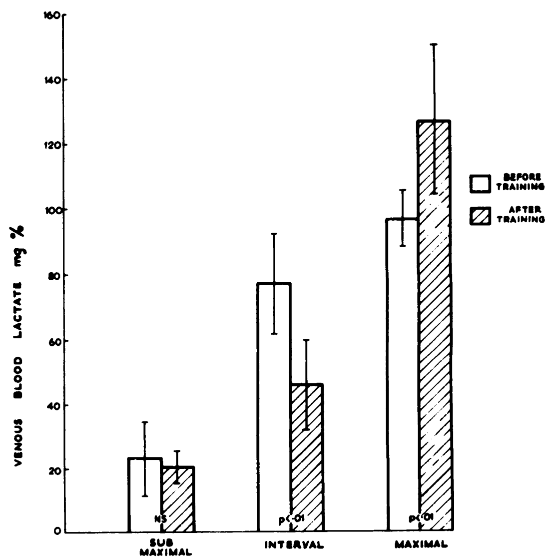

FIGURE 4 EFFECTS OF TRAINING ON VENOUS BLOOD LACTATE 5 MINUTES AFTER SUB MAXIMAL, (12·9 km/hr, 0% grade, 10 mins). INTERVAL (5 sec. work, 10 sec. rest at 16·9 km/hr, 20% grade, 4 mins). AND MAXIMAL TREADMILL RUNS.

VALUES GIVEN ARE MEANS. BRACKETS DENOTE S.D.

Maximal Run

In exhausting work, mean values of $\dot{V}O_2$ $\dot{V}_E$ and blood lactate increased by 6.2%, 8.2% and 31.6% respectively during the training period (Figures 3 and 4). Accounting for differences in the lengths of training periods, the percentage increase in $\dot{V}O_2$ max. appears comparable to that observed in other studies (4, 6, 8, 11, 25). The increase in the ability of the men to raise blood lactate in exhausting work (Figure 4) was a gross indication of greater glycolytic capacity. The values obtained are somewhat lower than those reported elsewhere (14, 24) but it is well recognised that motivation plays an important role in determining these limits. The increase in $\dot{V}_E$ in the maximum work test resulted, in part, from the higher concentrations of blood lactate. A 4 beats/minute reduction in maximal heart rate (Figure 3) agrees with data obtained in other studies (11, 23).

Interval Run

Figure 4 illustrates the marked reduction (40.4%) in blood lactate levels after 4 minutes of interval work at the training intensity. This adaptation may partially be the result of the increased capacity of the men to release oxidative energy thus enabling them to work at a lower percentage of their $\dot{V}O_2$ max. and incur a smaller lactacid oxygen debt. However it is suspected that an increased capacity of the alactacid oxygen debt mechanism is also respondible. This would provide a greater proportion of the energy required for these short work periods without restoring to help from the glycolytic pathway. Pyke et al (submitted for publication) have provided indirect evidence that the capacity of the alactacid mechanism is trainable in both young and older men and is highest in trained distance runners. More direct evidence of this from increased phosphagen (9) and myoglobin (21, 30) content of muscle following training is also available. However the results could be explained by the findings of Saltin and Karlsson (28) that the splitting of phosphagen in the trained state was less pronounced than when untrained and working at the same absolute load. Circulatory factors contributing to acceleration of oxygen transport at the onset of work and to faster removal of lactate during recovery from work could also account for the observed result.

Anaerobic Power Tests

The men did not improve in any of the anaerobic power performance tests (Figure 5) indicating that the stimulus for speed improvement was not present in the treadmill training regime. Inspection of data obtained by Pyke et al* on the men when employing film analysis of certain biomechanical features of their running gait provides a possible explanation. The average stride rate measured during a maximale track sprint was 4.15 strides/second with an average stride length of 2.29 metres. During treadmill training at 16.9 km/hour up a 20% grade the stride rate and length averaged only 3.40 strides/second and 1.38 metres respectively. Such a reduction in rate and length of stride seems incompatiable with promoting improvement in overground sprinting tasks (7). It should be noted that two subjects strained hamstring muscles in their first exposure to track sprinting after completing the training programme. Others complained of soreness in this muscle group suggesting that such explosive activities should be more gradually re-introduced.

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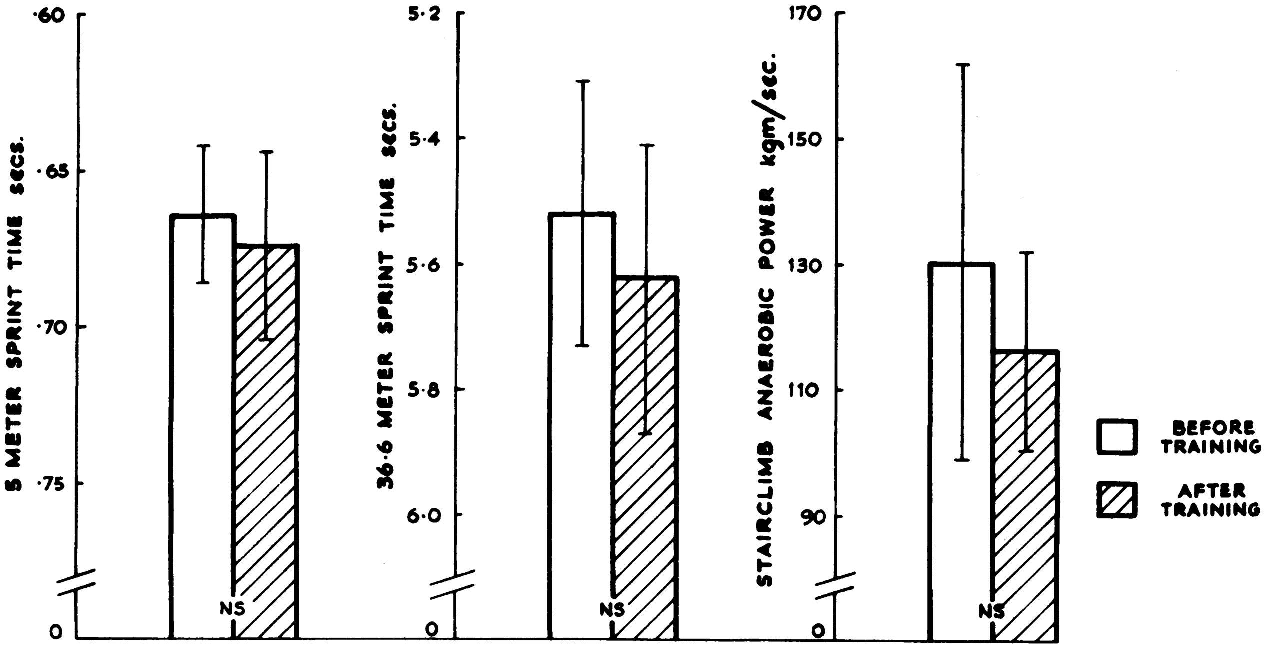

FIGURE 5 EFFECTS OF TRAINING ON 5 METER AND 36·6 METER (40 YARDS) SPRINT TIMES AND STAIRCLIMB ANAEROBIC POWER

VALUES GIVEN ARE MEANS. BRACKETS DENOTE S. D.

Conclusion

It was concluded that the interval treadmill training regime is a very effective method of producing a high total work output in a relatively short training session and thereby improves aerobic power, glycolytic capacity and ability to tolerate the short duration interval work encountered in many games. However, the training is exhausting and monotonous and only recommended for individuals highly motivated to improve their capacity for performance in competitive sports.

Acknowledgement

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