HEART RATES AT SUBMAXIMAL RELATIVE WORKLOADS IN SUBJECTS OF HIGH AND MEDIUM FITNESS

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ABSTRACT

Eight subjects of high fitness (VO_2 max - 56.9 ml/kg x min) and eight subjects of medium fitness (VO_2 max = 43.4 ml/kg x min) pedalled a bicycle ergometer for 6 minutes at workloads which elicited 70%, 80% and 90% of their individual VO_2 max. Heart rates were recorded during the last 30 seconds of each workload.

The data were analysed by a 2 (fitness levels) x 3 (workloads) analysis of variance factorial design. Although the high fitness group recorded a lower mean heart rate for the 3 workloads (155 beats/min) than the medium fitness group (161 beats/min), there was no overall statistically significant difference between the 2 fitness levels. The difference was most marked at the highest workload where a statistically significant ($p < .05$) interaction occurred between workload and fitness level. A completely randomised design analysis of variance indicated that the high fitness group attained their VO_2 max at a statistically significant lower heart rate (173 beats/min) than the medium fitness group (182 beats/min).

Introduction

The literature contains numerous reference to the fact that trained persons have lower heart rates than untrained subjects at absolute submaximal workloads. This is assumed, reasonably, to be due to the greater stroke volume of the former. However, little information has been published regarding the existence of any differences at submaximal workloads. Thus the purpose of this study was to compare statistically the heart rates of high and medium fitness groups when the subjects experienced submaximal relative workloads of 70%, 80%, and 90% of their VO_2 max on the bicycle ergometer. A secondary purpose was to effect a between-fitness level comparison of the heart rate at which VO_2 max was attained.

Method

The high fitness group comprised members of the Washington D.C. roadrunner's club whereas the medium fitness group consisted of graduate Physical Education students. Initially all subjects were tested for VO_2 max by the indirect open circuit method of calorimetry. The outlet of a triple "J" high velocity respiratory valve was connected to a Hans Rudolph five-way valve by means of a metre length of 3.8 cm internal diameter plastic tubing. This enabled expired air to be collected in 150 l Douglas bags. A Collins motor blower aspirated the expired air through a Singer dry gas meter. Expired gas samples were analysed for O_2 and CO_2 by paramagnetic and infrared gas analysers respectively. A computer programme was used to determine the VO_2 values (9).

The first visit to the laboratory consisted of continuous workloads of 150 Joules and 210 Joules (900

and 1260 kgm/min) for 6 and 5 min respectively. The Monark bicycle ergometer was equipped with toeclips and pedalled at a cadence of 60 rpm. Heart rate was recorded by means of a Beckman Type RS Dynograph for the last 30 seconds of each workload in this experiment using a CM5 electrode placement. Expired air was collected during the last minute of each workload period and VO_2 max was estimated from the Åstrand-Rhyming nomogram (1). The final workload for the first visit was an initial 2½ min warmup at 150 Joules (900 kgm/min) followed by a 2½ min workload which was estimated to require an oxygen uptake approximately 15% greater than the predicted value. Expired air was collected during the last 30 seconds of the workload. This was the pattern for subsequent visits to the laboratory. Sometimes it was necessary to collect air from 1½-2 or 1¾-2¼ min of exercise. Åstrand and Saltin (2) have shown that the heavier the workload then the faster the increase in VO_2 . Thus provided there is an adequate warmup period the work time at these high workloads can be shorter when compared with lower workloads. Maximum oxygen uptake was decreed to have been attained at that point at which an increase in workload of 30 Joules (180 kgm/min) elicited a rise in VO_2 of 150 ml/min or less. The reliability coefficient for VO_2 max in ml/kg x min for the 16 subjects was .950.

The inclusion of submaximal loads for each subject meant that it was possible to construct individual graphs of oxygen uptake versus workload. These graphs were then interpolated to determine the workloads which were necessary to elicit 70%, 80%, and 90% of each subject's VO_2 max. The order of performance of the 3

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submaximal workloads was then assigned randomly to each subject in the 2 fitness levels. Each of these workloads was of 6 min duration and preceded by a 2½ min warmup at 60% of VO_2 max.

Results

The descriptive statistics for the 2 fitness levels are contained in Table I. The VO_2 max means for the high and medium fitness groups were 56.9 and 43.4 ml/kg x min respectively.

The exercise heart rate was based on the last 30 seconds of each workload. The data was analysed by a 2 (fitness levels) x 3 (workloads) analysis of variance factorial design with repeated measures on workloads. Table II is a summary of the analysis. The .05 probability level was used for all tests of statistical significance. The tests for the 3 null hypotheses may be summarised as follows:

- 1) A test of "B" or fitness levels effect was conducted with 1 and 14 degrees of freedom. The null hypothesis was found to be tenable. The mean heart rates, when summed across all three workloads, were 161.4 and 155.2 beats/min for the medium and high fitness groups respectively. It was these two means which were found not to differ statistically.
- 2) The test for "A" or workloads effect was evaluated with 2 and 28 degrees of freedom. The three means for the combined fitness levels were 147.9, 156.9, and 170.4 beats/min when working at 70%, 80%, and 90% of VO_2 max respectively. The null hypothesis was rejected and a Newman-Keuls post-hoc test revealed that all three heart rate means differed from each other at the .05 level.
- 3) The AB interaction (workloads x fitness levels) test with 2 and 28 degrees of freedom revealed a statistically significant F ratio of 3.47. A Newman-Keuls post-hoc test indicated that interaction occurred at the 90% VO_2 max workload. The interaction was due to the fact that there was a greater difference in heart rate between the 2 fitness levels at this highest workload than at either of the 2 lower workloads. This is well demonstrated in Figure 1.

Table I

Descriptive Statistics for Age, Height, Weight, and Maximum Oxygen Uptake of the Medium and High Fitness Groups

	Medium Fitness (n = 8)		High fitness (n = 8)	
	Mean	S.D.	Mean	S.D.
Age in Years	26.0	1.8	24.6	4.6
Height in Cm	177.3	5.3	178.0	4.3
Weight in Kg	76.5	.1	65.4	4.9
VO_2 max L/Min	3.2	.2	3.7	.3
VO_2 max Mls/kg x min	43.4	3.0	56.9	3.2

Table II

Analysis of Variance for Heart Rates

Source	D.F.	S.S.	M.S.	F.
Between Subjects				
Fitness Levels (B)	1	462.52	462.52	1.96
Subjects (S)	14	3302.45	235.89	
Within Subjects				
Workloads (A)	2	3961.50	1980.75	88.50 ^a
Interaction (AB)	2	155.17	77.59	3.47 ^a
Error (AS)	28	626.67	22.38	
Total	47	8508.31		

^a Significant at the .05 level

Figure 1. Heart Rates at Submaximal Relative Workloads in Subjects of High and Medium Fitness.

Finally, a completely randomised design analysis of variance was run on the heart rate/min at which VO_2 max was attained in the 2 fitness groups. This analysis resulted in a statistically significant F ratio of 5.15. The two means were 181.5 and 172.9 beats/min for the medium and high fitness groups respectively.

Discussion

The mean VO_2 max of the high fitness group of 57 ml/kg x min is well below the mean VO_2 max of 71 ml/kg x min for 6 marathon runners reported by Costill and Fox (5). However, all six subjects were marathon runners of national ranking whereas only one subject in this study, Jack Mahurin who finished 12th in the 1973 Boston Marathon, was a leading athlete. Moreover, Costill and Fox's data was a result of treadmill workloads and it has been demonstrated recently that VO_2 max values are 10.2 to 11.2% lower on the bicycle ergometer than on the treadmill (10).

The mean heart rates at which VO_2 max was attained were 182 and 173 beats/min for the medium and high fitness groups respectively. However, it is relevant to note that these were not maximum heart rates since Karlsson et al. (8) have observed that this parameter is still capable of increasing even though the oxygen uptake curve has levelled off.

Figure 1 portrays the well known Linear relationship between VO_2 and heart rate at submaximal workloads. Accordingly the 3 heart rate means of 148, 157 and 170 beats/min at 70%, 80%, and 90% VO_2 max for the combined fitness levels were all statistically different from one another at the .05 level. Figure 1 also demonstrates that the high fitness group experienced lower heart rates at each of the three submaximal relative workloads. However, the overall difference between the fitness levels was not statistically significant. A similar

conclusion was reached by Eckblom (6) when evaluating the effect of a 22 week training programme on the heart rate at workloads which elicited 10%, 20%, 30%, 40%, 50%, and 60% of VO_2 max. Bock et al. (4) were probably the first investigators to show that trained persons have a lower heart rate than untrained persons at absolute submaximal workloads due to their larger stroke volume. This has been confirmed by subsequent research (3, 11, 12, 13). It is therefore relevant to note that differences in heart rate, albeit statistically insignificant, still existed between the two fitness levels in this study when all subjects worked at submaximal relative workloads. In such circumstances differences would be smaller than with absolute workloads. The presence of a significant interaction between the two fitness levels for the heart rate at the 90% VO_2 max workload indicates that the difference between the two groups was significantly greater at this highest workload. This is depicted well in Figure 1. A similar trend has been noted when comparing athletes with sedentary people at absolute workloads (7, 12) and is no doubt due to the greater cardiac stroke volume of the former.

Acknowledgements

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ERRATA

Mr. R. T. Withers has requested that the following errors be pointed out in his article that appeared in the last issue, Vol. 9 No. 4. Heart rates at submaximal relative workloads in subjects of high and medium fitness. R. T. Withers and R. W. Haslam.

The author wishes to stress that the following errors were not in the original manuscript:

Abstract p. 187

- 1st paragraph line 1 — each $\dot{V}O_2$ max to be preceded by $\bar{x}$
- 2nd paragraph line 2 — read 155.2 beats/min in lieu of 155 beats/min.
- 2nd paragraph line 3 — read 161.4 beats/min in lieu of 161 beats/min.
- 2nd paragraph line 6 — read 172.9 beats/min in lieu of 173 beats/min and 181.5 beats/min in lieu of 182 beats/min.

Introduction p. 187

Line 7 to read: "differences at submaximal **relative** workloads . . ."

Method p. 187

- 1st paragraph line 8 to read: "of a 1.067m length of 3.81cm . . ."
- 2nd paragraph line 2 to read: "continuous workloads of 147 and 205 **watts** (900 . . ."
- 2nd paragraph line 10 to read: "and $\dot{V}O_2$ max was estimated from the Astrand — **Ryhming** . . ."
- 2nd paragraph line 12 to read: "an initial 2½min warmup at 29.4 **watts** (900 kgm/min . . ."
- 2nd paragraph line 25 to read: "point at which an increase in workload of 29.4 **watts** (180 . . ."
- 3rd paragraph line 7 to read: "submaximal workloads were then **randomly assigned** to . . ."

Results p. 188

2nd paragraph line 2 to read: ". . . The data **were** . . ."

Discussion p. 189

- 1st paragraph line 1 to read: 56.9 in lieu of 57.
- 1st paragraph line 2 to read: 71.4 in lieu of 71.
- 2nd paragraph line 2 to read: 181.5 and 172.9 in lieu of 182 and 173.
- 3rd paragraph line 1 to read: linear in lieu of Linear
- 3rd paragraph line 3 to read: 147.9, 156.9 and 170.1 in lieu of 148, 157 and 170.

References p. 189

Number 1: read **RYHMING** in lieu of RHYMING.

The Editor offers his apologies to the authors errors in proof reading and for making some alterations not approved by the authors.