OXYGEN DEBT AND RISE OF BLOOD LACTATE DURING SUBMAXIMAL EXERCISE IN RELATION TO PHYSICAL FITNESS AND ENDURANCE

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Oxygen debt and rise of blood lactate during graded submaximal work were linearly related to each other and to work rate. They could also differentiate the physical fitness status of groups of individuals, being lower for better fit groups. Such differentiation was, however, possible only above work rates of the order of 500-600 kg.-m./min. The significance of this in submaximal tests for physical fitness is pointed out. Value of oxygen at which blood lactate begins to rise was significantly higher in better fit group. Oxygen debt and rise of blood lactate during a standard near maximal exercise could reflect work capacity in terms of maximum stepping time on a 16 in. high stool.

The study of physiological and biochemical parameters under submaximal work rates and their relationship with tests of physical fitness and efficiency under more severe work rates is of much interest. Two of these parameters, namely, oxygen debt and rise of blood lactate have been systematically studied by us at various submaximal work rates. Considerable amount of information is available in literature regarding blood lactate during strenuous exercise and recovery [1-5]. Relationship of blood lactate with grades of work[6], maximal oxygen uptake[7], physical efficiency[8,9] and physical training[10] has also been reported. However, very little information is available in literature regarding the relation between oxygen debt and physical fitness/efficiency. The inter-relationship between oxygen debt and rise of blood lactate at graded submaximal work rates, and the relation of the two parameters to physical fitness and work capacity tests have been investigated.

EXPERIMENTAL PROCEDURE

Three experiments[11] were performed on a total of 33 male clinically normal subjects of whom 21 (10 in Expt. 1 and 11 in Expt. II) were military personnel (age 21—31 years height 157—177 cm. and weight 48-67 kg.), engaged mostly in sedentary duties and 12 were Physical Training students (age 21—24 years, height 158—174 cm. and weight 46—67 kg.). The Harvard Step Test[12] was applied to all subjects as a test of physical fitnesss. The score obtained in this test is referred to as the fitness score. Maximum stepping time on 16 in. high stool at the rate of 30 cycles/minute was determined as a test of endurance, in Expt. II only, and is referred to as the endurance time. In this test, each subject was prompted to go to his maximum. As a check, the recovery pulse during 1—1½ ft. after cessation of stepping was counted; if this was around 70, it was assumed that the subject had exerted his maximum. Oxygen debt and rise of blood lactate were determined on all subjects during a standard task comprising stepping on 15″ high stool at the rate of 30 cycles/minute. In addition, subjects in Expt. I performed the stepping task on 8″-20″ high stools and the oxygen cost and work rate for the tasks were determined as described elsewhere[11]. All experiments were done in the post-absorptive stage between 0900 and 1200 hours. Mean Dry Bulb temperature and Relative Humidity were respectively 29°C and 63 per cent.

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RESULTS

Oxygen debt and rise of blood lactate in relation to work rate

Mean values of oxygen debt and rise of blood lactate at various work rates for all subjects in Expt. I are shown in Fig. 1 and 2 respectively. Analysis of individual values showed that the two parameters were highly correlated with work rate ($P < \cdot 001$). Within the work rates included in this study, linear regressions fitted the data well (Fig. 1 and 2, continuous lines).

Oxygen cost of work, oxygen debt and rise of blood lactate in relation to physical fitness

It appeared from individual data in Expt. I that among subjects with appreciably different fitness scores, those with higher scores tended to have lower oxygen debt and rise of blood lactate and *vice versa*. This relationship was not consistent among subjects whose fitness scores were relatively close to one another. However, when two groups, each of four subjects, with widely different mean fitness scores were formed from among the 10 subjects in Expt. I, one group with a mean score of 85 and range 80-88 (more fit group) and the other with a mean score of 61 and range 58—64 (less fit group), it was found that the mean values of oxygen debt and rise of blood lactate in the less fit group were consistently higher than in the more fit group (Figs. 1 and 2). Mean values for the remaining

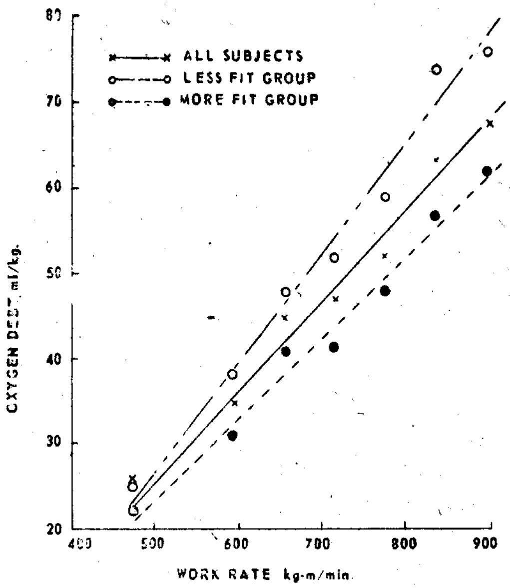

Fig. 1—Relation between oxygen debt and work rate.

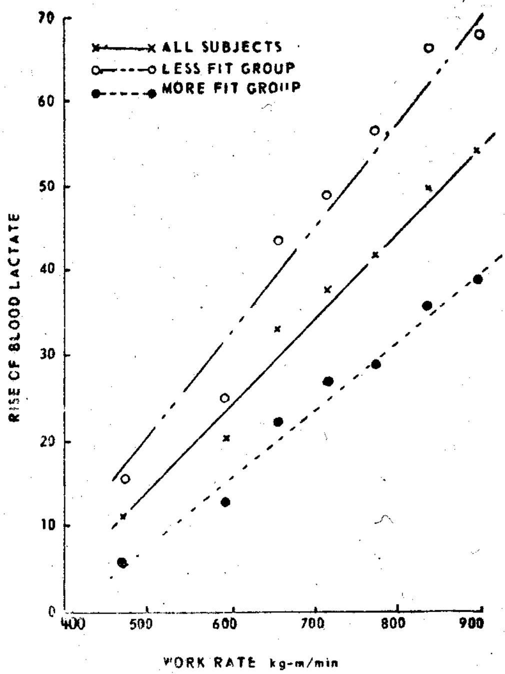

Fig. 2—Relation between rise of blood lactate and work rate.

two subjects (scores 70 and 72) generally lay between the corresponding values for the less and more fit groups. Analysis of individual data for the latter two groups showed that :

(*a*) Regression lines for oxygen debt against work rate (Fig. 1, broken lines) were significantly different for the two groups with respect to (*i*) the expected values of oxygen debt at work rates above 600 kg-m/min. ($P < \cdot 05$), and (*ii*) the regression coefficient ($P < \cdot 05$) . Both (*i*) and (*ii*) were higher in the less fit group, meaning that in this group, the oxygen debt at a given work rate was higher and also rose more steeply with increasing work rate than was the case in the more fit group. At work rates below 600 kg-m/min there was no significant difference between the expected values of oxygen debt in the two groups.

(*b*) Regression lines for rise of blood lactate against work rate (Fig. 2, broken lines) were significantly different for the two groups, with respect to (*i*) the expected values of rise of blood lactate at work rates above 450 kg-m/min. ($P < \cdot 05$), the significance being lost at lower work rates, and (*ii*) the regression coefficient ($P < \cdot 01$). Both (*i*) and (*ii*) were higher in the less fit than in the more fit group, the meaning being similar to that for oxygen debt, given under (*a*) above.

(*c*) The relationship between oxygen debt and rise of blood lactate at various work rates for the two fitness groups could be represented by linear regression lines (Fig. 3) which were significantly different with respect to the expected values of oxygen debt at various values of rise of blood lactate ($P < \cdot 05$). The two regression coefficients were very close to each other and the difference between them was non significant. This would indicate that the energy equivalent in terms of unit weight of lactic acid formed in the body during anaerobic metabolism was similar for the two fitness groups. A similar inference may be drawn from the data of Margaria *et al*[4] on athletic and non-athletic subjects. Also, the two regression lines, when extrapolated, gave intercepts on the ordinate, which corresponded to oxygen debt values of 18·5 and 10 ml./kg. respectively for the more and less fit groups. On the basis of a common regression coefficient (the difference between the regressions for the two groups being non-significant), the difference between these two values of oxygen debt was significant ($P < \cdot 05$). Assuming that extrapolation was valid, this observation would mean that in the more fit group, rise of blood lactate during exercise would begin after a greater amount of oxygen debt had been contracted, than was the case in the less fit group.

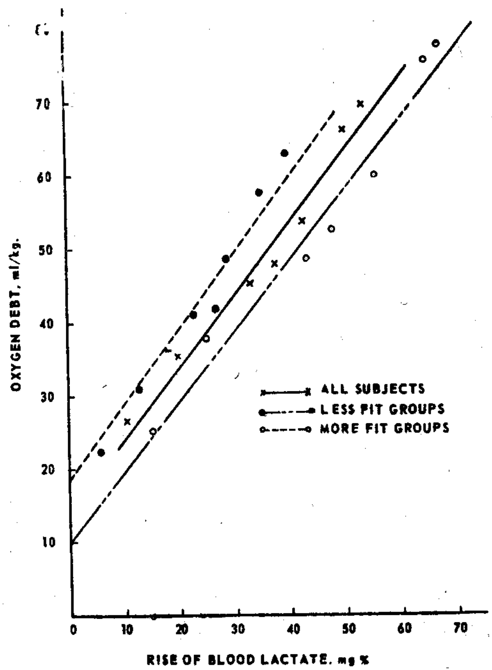

Fig 3—Relation between oxygen debt and rise of blood lactate at various work rates.

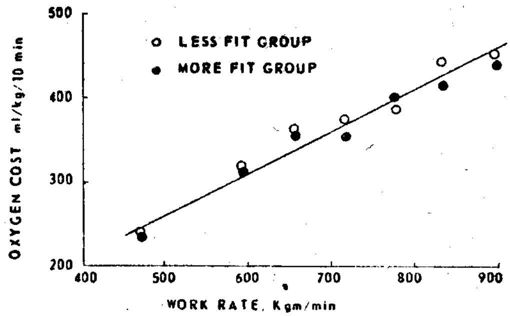

Fig. 4—Relation between oxygen cost of work and work rate.

(*d*) The relation between oxygen cost of work and work rate was linear and the difference between the regression lines for the two fitness groups was non-significant. Mean values for the two groups and regression line based on values for all the 10 subjects in Expt I are given in Fig. 4. It would appear that physical fitness is a negligible factor in the energy requirements for submaximal work. Similar results have been reported elsewhere[13, 14].

Oxygen debt and rise of blood lactate during the standard stepping task on 15 in. high stool in all the three experiments have been plotted against the respective fitness scores in Fig. 5 and 6 respectively. Highly significant correlations ($P<\cdot 01$) existed between fitness score and oxygen debt, as well as between fitness score and rise of blood lactate. The relations were probably curvilinear, but have been represented by linear regression lines (continuous lines) in the Figures. Lines representing $\pm$ S. D. (Standard Deviation) have also been drawn (broken lines). The magnitude of the S.D. is such that, for a given observed value of oxygen debt or rise of blood lactate, the range of probable values of fitness score is appreciably wide.

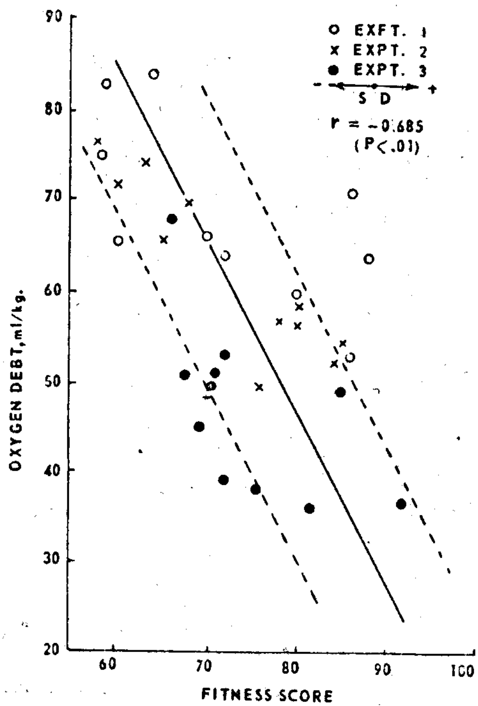

Fig. 5—Relation between oxygen debt for stepping task on 15″ stool, and fitness score.

Oxygen debt and rise of blood lactate in relation to physical endurance

Values of oxygen debt and rise of blood lactate during the standard stepping task on 15 in. high stool in Expt. II have been plotted againstthe corresponding endurance times for the individuals in Fig. 7 and 8 respectively. In Fig. 9, fitness scores have been plotted against endurance time. Significant correlations existed between oxygen debt and endurance time ($P<\cdot 02$), between rise of blood lactate and endurance time ($P<\cdot 05$) and between fitness score and endurance time ($P<\cdot 005$).

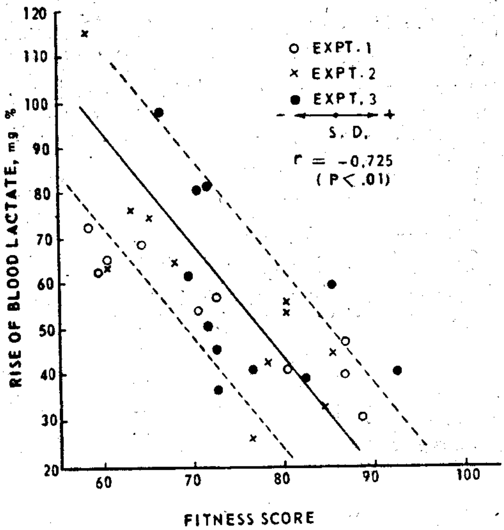

Fig. 6 —Relation between rise of blood lactate for stepping task on 15″ stool and fitness score.

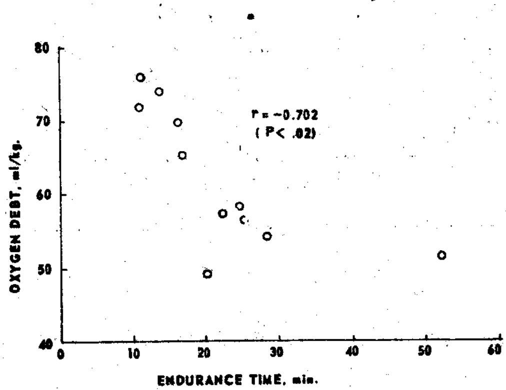

Fig. 7—Relation between oxygen debt for step ping task on 15″ stool and endurance time for stepping on 16″ stool.

DISCUSSION

Oxygen debt and rise of blood lactate are measures of the anaerobic component in muscular work. During submaximal work the anaerobic component is relatively low, as also the magnitude of oxygen debt and rise of blood lactate. On the other hand, the Harvard Step Test utilises a work rate which is near maximal/maximal and, as such, affords a measure of cardiovascular efficiency of the individual. In field studies[15], fitness score was found to he highly correlated ($P < \cdot 01$)with running time for 1 and 2 miles with

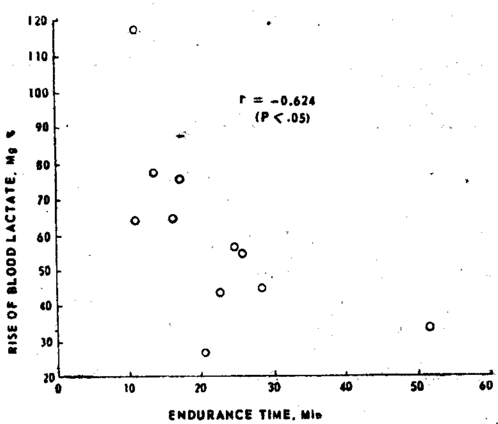

Fig. 8—Relation between rise of blood lactate for stepping task on 15″ stool and endurance time for stepping on 16″ stool.

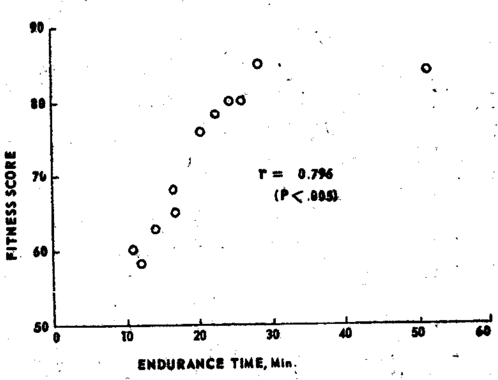

Fig. 9—Relation between fitness score and endurance time for stepping on 16″ stool.

and without extra load on the body. In the present work also, fitness score was well correlated with endurance time for stepping (near maximal work rate). The correlations observed between oxygen debt and rise of blood lactate as measures of anaerobic metabolism during submaximal work on the one hand, and fitness score on the other are interesting. They indicate that even at submaximal work rates, these measures of the anaerobic component do have a bearing on the organism's maximal capacity for cardiovascular function. This is so, because at such submaximal work rates the demands on the cardiovascular system are relatively low. Further, these studies indicate that factors other than oxygen debt and rise of blood lactate also influence the fitness score. It must be emphasised that at low work rates (below about 500-600 kg.-m/min.) the fitness groups could not be distinguished from each other in terms of oxygen debt or rise of blood lactate. This observation is of practical importance in that while designing submaximal tests for physical fitness, the work rates would have to be kept above a minimum which may be of the order of 600 kg.-m/min.

From studies of the kinetics of oxygen consumption during recovery after exercise, it has been postulated that oxygen debt has an alactic component (i.e., not involving the disappearance of lactate) which chiefly constitutes the fast initial phase of the recovery[3, 16]. It may be expected that during contraction of oxygen debt also, there would be an alactic, probably initial, phase in which lactic acid is not formed. Oxygen debt for zero rise of blood lactate, obtained by extrapolation in the present study, might represent this alactic phase. If so, it would appear that physical fitness is in some manner associated with the efficieny of the alactic mechanism for contracting oxygen debt. Oxygen debt for zero rise of blood lactate, obtained in this way, may be termed 'threshold oxygen debt'.

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