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ABSTRACT

Maximal oxygen intake and associated physiological variables were measured during strenuous exercise on women subjects (N=20 physical education majors). Following assessment of maximal oxygen intake, all subjects underwent a performance test at the work level which had elicited their maximal oxygen intake. Mean maximal oxygen intake was 41.32 ml./kg./min. and mean maximal heart rate was 185.8 bts./min. In the endurance performance test, the mean run time for all subjects was 4:35.8 minutes. Correlation between maximal oxygen intake and performance time was significant (r=.066). However, a highly significant correlation was obtained between maximal oxygen intake and physical work done during the performance test (r=.64). A two-page bibliography is included, along with three tables of statistical data. (Author/BRB)

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MAXIMAL OXYGEN INTAKE AND MAXIMAL WORK PERFORMANCE OF ACTIVE COLLEGE WOMEN

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Abstract

Maximal oxygen intake and other associated physiological variables were measured during strenuous exercise on fairly active women subjects (N = 20, physical education majors). The method described by Taylor et al. (14) was essentially used. Following assessment of maximal oxygen intake, all subjects underwent an all-out performance test at the work level which had elicited her maximal oxygen intake. Mean maximal oxygen intake was 41.32 ml./kg./min. and mean maximal heart rate was 185.8 bts./min. In the endurance performance test the mean run time for all subjects was 4:35.8 minutes. Correlation between maximal oxygen intake and performance time was calculated and found to be insignificant ($r = .066$); however, a highly significant correlation was obtained between maximal oxygen intake and physical work done during the performance test ($r = .64$).

Introduction

(1) To date very little research has been conducted on women performing at intense work levels. The sociological stigma against severe exercise for women provides a partial rationale for this dearth of research. In addition, there is no doubt that a certain reluctance by

many women to work at exhaustive levels of exercise also exists. However, there is a great need for enhancing our knowledge of the physiologic responses which take place in women during heavy exercise; in the world of sport the trend is increasing toward more and more endurance activities for women. If coaches are to be effective, and if women athletes are to reach the heights of performance they are capable of, then our knowledge in this area must be increased. The purpose of this study was to (1) determine maximal oxygen intake for active college women, (2) to investigate the length of time an individual can perform at the work level which elicited her maximal oxygen intake. A sub-problem was to study the relationship of maximal oxygen intake to (a) the length of time a person can work at her maximal level and (b) total physical work done during the run.

Review of Literature

(2) Assessment of maximal oxygen intake of women using continuous and intermittent work capacity tests on either the treadmill or bicycle ergometer have produced remarkably consistent findings for college age women. For highly trained women, mean values ranged from 46 to 55 ml./kg./min. (6, 9, 1). The highest maximal oxygen intake reported for a woman athlete has been 68.4 ml./kg./min. (6). Mean maximal oxygen intake values for fairly active women of college age fell between 37 and 39 ml./kg./min. (6, 15, 5, 9) and untrained women are reported to average around 30 ml./kg./min. (11).

(3) Scant research has dealt with the length of time a person can continue to work at that level which elicited maximal oxygen intake. However, recently Horvath and Michael (7) tested fourteen women subjects (ages 18 - 37) at the work level at which they had reached their maximal oxygen consumptions. They found that a woman performing at this severe workload on a bicycle ergometer will reach exhaustion in two to four minutes. Astrand and Saltin (4) measured the length of time it took subjects to reach (a) maximal oxygen intake, (b) exhaustion. Astrand's one female subject became exhausted at all workloads immediately on reaching or before reaching her maximal oxygen intake. However, the four male subjects were able to continue for some time at most workloads after reaching their maximal oxygen intake. Robinson (12) collected data on men exercising at a rate which produced exhaustion within five minutes and found that all subjects attained 90 - 98% of their maximal oxygen intake during the second minute of the run. Astrand (3:340) also investigated the relationship between physical exhaustion and oxygen intake. He found that when the treadmill speed was decreased from the work level which brought about complete exhaustion in four minutes, a decrement in speed of as much as 3 m.p.h. did not lower the oxygen intake of some subjects.

Procedure

(4) Twenty women physical education majors from the University of Minnesota volunteered to take part in this study. At the time of this investigation, 8 of the subjects were playing on an extramural basketball team which practiced three times per week. The remainder of the subjects were active in recreational activities.

(5) The assessment of maximum oxygen intake was essentially the method described by Taylor, Buskirk, and Henschel (14). It was necessary to make some adjustment in the treadmill running speed suggested by Taylor et al. because of the use of women subjects; a speed of five, six or seven miles per hour was selected for each participant. Running speed was established by questioning each subject on her current exercise pattern and by observing her efficiency of running on the treadmill. A minimal rest period of fifteen minutes was allowed between three-minute runs. No more than two three-minute runs were completed on any one day and, at strenuous workloads, only one run was undergone. All subjects underwent a warm-up at the beginning of each testing session which was continued until heart rate reached 150 bts./min. The grade for the initial run was 2½ percent and was increased for each successive run until the increment in oxygen consumption from one grade to the next was less than one cubic centimeter per kilogram of body weight. At this point of leveling off in oxygen consumption, the individual was considered to have reached her maximal oxygen intake. The number of runs necessary to elicit maximal oxygen intake ranged from three to eight, however, most individuals reached their maximal in about five runs. Several related physiological measures were used as additional criteria to verify the attainment of maximal oxygen intake: ventilatory volume, oxygen extraction ratio, respiratory quotient, and maximal heart rate.

(6) Following the assessment of maximal oxygen intake each individual underwent a performance run at the grade and speed which had elicited her maximal oxygen intake. In cases where an oxygen intake plateau was

shown by the subject for two or more grade levels, ventilatory volume, oxygen extraction ratio, respiratory quotient and maximal heart rate were employed in the selection of the work level. In general, the grade selected was the one at which the individual's values for the above variables were similar to the mean values at performance grade levels selected for the other subjects. This run was done under controlled conditions in which no verbal encouragement or extrinsic motivation of any kind was given to the subject during the performance. Before the start of the run each subject was told that it was an all-out endurance performance test and encouraged to continue for as long as possible. Physical work done during the performance run was calculated in foot pounds.

(7) Oxygen concentrations in the expired air were analyzed using Beckman oxygen and carbon dioxide analyzers. For purposes of validation, duplicate oxygen and carbon dioxide analyses were done on 24 expired air samples utilizing the Haldane apparatus. Pulse rates were recorded by radio telemetry immediately before and during the last 15 seconds of each run to determine maximal oxygen intake. Heart rate was also recorded immediately before the performance run, at the end of each minute during the run, and at the termination of the run.

Results

(8) A correlation coefficient of .97 was obtained between the oxygen intake values calculated from the Beckman and Haldane oxygen and carbon dioxide readings.

(9) The mean oxygen intake for active college women in the present study was 41.32 cc./kg./min. Individual values ranged from 31.69 to 51.49 cc./kg./min.

(10) Several physiological measurements were made in conjunction with the assessment of maximal oxygen intake. Oxygen intake, ventilation and R.Q. all showed a steady rise with increasing workload while oxygen extraction fell progressively. Terminal heart rate rose abruptly between the first two grade levels and then continued to increase gradually with further increase in workload. The mean maximal heart rate during the assessment of maximal oxygen intake was 185.8 bts./min.

(11) The mean run time for the endurance performance run, done under conditions of no extrinsic motivation, was 4:35.8 min. The correlation between maximal oxygen intake and performance time, was insignificant ($r = .066$). However, the relationship between maximal oxygen intake and total physical work done during the performance run as found to be highly significant ($r = .64$).

Discussion

(12) Table I shows a comparison of the mean maximal oxygen intake found in the present study with results of other investigators who tested different groups of women athletes and non-athletes. The data tends to fall into 3 distinct categories related to level of training. The mean maximal oxygen intake found in the present study concurs closely with the findings of other investigators for different groups of fairly active women. However, 41.32 cc./kg./min. (the mean maximal oxygen intake in the present study) is the highest value reported for any group in the

fairly active category. There are two possible explanations for this: (1) assessment of maximal oxygen intake while running on a treadmill has been shown to elicit higher values than assessment utilizing the bicycle ergometer; (2) since many of the subjects in the present study were concurrently playing on an extramural basketball team their level of training could have been higher than the other groups in the fairly active classification. The mean maximal oxygen intake value found in the present study can be compared with the mean of 38.80 cc./kg./min reported by Sinning and Adrian (13) for intercollegiate basketball players.

(13) A summary of the findings on the relationship between maximal exercise heart rate and level of training in women is presented in Table II. Although Sinning and Adrian (13) and Hermansen and Andersen (6) found that their trained groups had lower maximal heart rates than untrained groups, this finding is not supported by other data reported in Table II (9, 11). If there is a relationship between level of training and maximal heart rate during severe exercise, it is probably being obscured here by the fact that the heart rates reported by different investigators were elicited during several different types of tests to measure maximal oxygen intake.

(14) Astrand (3:209) found that the maximal oxygen intake an individual can attain is directly related to maximal pulmonary ventilation. This relationship seems to be supported by the data reported in Table III. In the present study the mean maximal ventilation was 90.6 l./min. This value was higher than that reported by Sinning and Adrian (13) for their two groups: basketball players - 87.5 l./min; untrained - 89.8 l./min.

(15) Under conditions of no extrinsic motivation, it was found that the average run time for all subjects working at the level which had elicited maximal oxygen intake was 4:36 min. Horvath and Michael (7) reported that subjects working at the level which elicited their maximal oxygen intake on the bicycle ergometer reached exhaustion between 2 and 4 minutes. This is considerably less than the mean run time of subjects in the present study; however, it is difficult to equate bicycle riding and treadmill running. Also, the subjects of Horvath and Michael were in much poorer physical condition, than those in the present study as indicated by the reported mean maximal oxygen intake (29.80 cc./kg./min.). An investigation by Robinson (12) indicated that it is difficult for anyone to work longer than three minutes after reaching maximal oxygen intake. The results of the present study concur closely with this statement in that all subjects should have reached maximal oxygen intake within the first three minutes of exercise and only two subjects ran for more than 6 minutes. In a continuous work test on the bicycle ergometer, Astrand and Saltin (4) found that the one female subject in the experiment became exhausted as soon as she reached her maximal oxygen intake. However, four male subjects in the study were able to continue work for a short time after reaching maximal oxygen intake. It is likely that the difference in ability to continue work at maximal between Astrand's female subject and the subjects in the present study is related to the difference in the two work tasks employed. Astrand and Saltin used a continuous, progressive work task initiated at a submaximal level and continuing over a much longer period of time than the test employed in the present study. The fatigue effects

of prolonged exercise would undoubtably influence an individual's ability to continue work at the level which elicited maximal oxygen intake. Another study by Astrand (3:340) demonstrated that workloads which produced exhaustion within 4 minutes were often as much as 3 m.p.h. above that workload which elicited the subject's maximal oxygen intake. These results concur with the findings of the present study which indicate that the individual's tolerance for physical work is at a level somewhere above that work level which elicited maximal oxygen intake.

(16) A secondary problem of this study was to investigate the relationship between a person's physiological capacity for endurance and her ability to perform endurance work at her maximal level. Although there has been little previous research in this area, it was hypothesized that an individual with a higher maximal oxygen intake would be able to perform for a longer period of time at her maximal level. Anaerobic capacity and motivation should have been the two most important variables influencing performance time. If a relationship exists between anaerobic capacity and aerobic capacity it should have been revealed in the correlation coefficient between run time and maximal oxygen intake. When the correlation was calculated the result was non-significant ($r = .066$). It can be concluded that little or no relationship exists between aerobic capacity and ability to sustain anaerobic metabolism.

(17) In the present study, the relationship between maximal oxygen intake and endurance was studied by correlating maximal oxygen intake with physical work done during the performance run. The result showed a highly significant relationship ($r = .64$) similar to findings of other

investigators (2, 10, 15). Astrand (3:309) states that in exercises of 1 minute or longer, no one can attain top results without high aerobic power. He further states "on the other hand, a high power does not guarantee a good performance, since technique and psychological factors may have a modifying influence in a positive or negative direction." This would explain why a significant but not perfect relationship is continually reported between maximal oxygen intake and endurance performance.

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TABLE I

COMPARISON OF MEAN MVO_2'S OBTAINED IN THIS STUDY

WITH VALUES REPORTED ON COLLEGE-AGE WOMEN BY OTHER INVESTIGATORS

Investigator	Level of Training	M	MVO_2 (ml./kg./min.)
Michael and Horvath (11)	Untrained	30	29.80
Higgs (present study)	Physical Education Majors	20	41.32
Goodhartz (5)	Active but Untrained	10	37.34
MacNab et. al. (8)	Physical Education Majors	24	39.06
Hermansen and Andersen (6)	European Non-Athletes	12	38.00
Sinning and Adrian (13)	Intercollegiate Basketball Players	7	38.80
Astrand I. (1)	Active but Untrained		39.90
Maksud et. al. (9)	Speed Skaters	13	46.10
Hermansen and Andersen (6)	Cross-Country Skiers	5	55.00
Astrand I. (1)	General (highly trained)		48.40

TABLE II

COMPARISON OF MEAN MAXIMAL HEART RATES ACHIEVED

BY DIFFERENT GROUPS OF WOMEN ATHLETES DURING MAXIMAL OXYGEN INTAKE TESTING

Investigator	Group	Maximal Heart Rate (bts./min.)
Higgs (present study)	P.E. Majors	185.8
Sinning and Adrian (13)	Basketball Players	184.6
	Untrained	187.5
Hermansen and Andersen (6)	Cross-Country Skiers	186.0
	Non-Athletes	203.0
Maksud *et. al.* (9)	Speed Skaters	192.0
Michael and Horvath (11)	Untrained	184.0

TABLE III

MAXIMAL PULMONARY VENTILATION AND MAXIMAL

OXYGEN INTAKE OF FOUR GROUPS OF WOMEN SUBJECTS

Group	MVO_2 (ml./kg./min.)	Max. Ventilation (l./min.)
Untrained (Sinning and Adrian)	36.2	89.8
Basketball Players (Sinning and Adrian)	38.80	87.5
Physical Education Majors (Higgs)	41.32	90.6
Speed Skaters (Maksud *et. al.*)	46.10	96.5