Chapter II

REVIEW OF RELATED LITERATURE

A review of related literature available in the library of Lakshmibai National College of Physical Education, Gwalior and Medical College, Trivandrum which are relevant to the present study are cited in this chapter.

In writing the reviews, firstly we would outline several general studies related to circulatory variables in general, then in the order specific variables such as heart rate, blood pressure, haemoglobin concentration and cardio-pulmonary index. Then we would switch on to the studies related to respiratory variables resulting from training programmes in the order respiratory variables in general, minute ventilation, tidal volume, respiratory rate and maximal oxygen consumption.

Pilch\(^1\) investigated the effect of regular periods of exercise, using a submaximal work load on the bicycle

\(^1\) Arthur Henry Pilch, "Cardiovascular Responses of selected Middle Aged Subjects to Regular Periods of Exercise" Dissertation Abstracts International 32:2 (August 1971):775 A.
ergometer on selected cardio-vascular respiratory measurements of randomly assigned middle-aged volunteers and also tried to determine whether the cardio-vascular measurements of these subjects after physical training would be similar to those of younger, active male volunteers.

The experimental group pedalled the bicycle ergometer thirty minutes per day, four days per week, for six weeks at a work load that kept the heart rate at 135 beats/minute. The cardio-vascular parameters that were measured before and after training were heart-rate, ventilation-rate, blood pressure, Oxygen Uptake and carbon dioxide expired. The analysis of data by using 't' test revealed that there was a significant improvement in heart rate at 750 and 1200 kilopound meters work load, and recovery levels. There was a significant improvement in systolic pressure at all levels except at the 1200 kilo pound meters work load. Diastolic blood pressure showed a significant improvement at the 300 and 750 kilo pound meter work loads. There were no significant changes in oxygen Uptake and carbon dioxide expired. There were no
significant changes in Haemoglobin from pre to post-training on the experimental group.

Koff. et. al.²; investigated cardiorespiratory responses to strenuous exercise in physically trained and untrained normal men. Twenty eight normal men were tested for exercise tolerance by making them walk on a treadmill at 5 mph and 18 percent grade to evaluate cardiorespiratory performance. Forty eight normal men, who were selected for their athletic training experience, had a preliminary walk for 3 min. at 5 mph and 18 percent grade, and then ran at 6.5 mph and 25 percent grade to the limits of their physical endurance to estimate maximal work capacity. This maximal test showed greater variance for endurance than either maximal oxygen consumption, ventilation or heart rate.

H. Williams and C. Williams³ developed a treadmill


walking test in order to provide a suitable method of assessing the fitness level of sedentary middle aged men (mean age, 44.3 years) at submaximal intensity. The test procedure was used in a preliminary experiment to compare the cardiovascular and metabolic responses of trained and untrained middle aged men to exercise. Heart rate response to the test were significantly higher in the untrained, compared with the trained men as were the post exercise blood lactic acid concentrations, respiratory exchange ratios, ventilatory equivalents and rate of perceived exertion. Haemoglobin concentrations were maintained at a normal level throughout the test period and there were no significant difference either between groups or before and after exercise.

Harger determined differences in the effects of two frequencies of high volume interval training on the metabolic and cardiorespiratory responses of untrained college men. Specially, the following variables were

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compared and analyzed before and after training. Maximum Oxygen consumption, physical work capacity, blood lactic acid concentration, maximum aerobic power, maximum ventilation, resting blood volume, resting heart rates, resting heart size, resting systolic intervals and resting haemoglobin concentration. He found that training four times weekly is not better than training two times per week in causing a decrease in maximal heart rate; both frequencies of training show a tendency to reduce resting haemoglobin as a result of seven weeks of high volume interval training.

Astrand, et.al.,\textsuperscript{5} pointed out that detailed information is needed regarding the reaction of the human organism during severe muscular work where part of the energy has to be delivered by anaerobic processes and where an increasing concentration of lactic acid limits the duration of work. One well-trained male subject exercised on an

\textsuperscript{5} P.O. Astrand et.al.; "Circulatory and Respiratory Adaptation to Severe Muscular Work" \textit{The Research Quarterly} 33:1 (March 1962):144.
ergocycle for different periods of time at a standard work load of 2,160 Kpm/min. Heart rate, pulmonary ventilation, and oxygen uptake reached identical values at a given time after the start of work.

Wallin and Schendel\textsuperscript{6} studied changes in heart rate and blood pressure in 21 sedentary business and professional men 31 to 60 years of age after participation in a 10-week jogging programme three days per week. The results showed that heart rates were reduced significantly in the resting state, at six minutes during exercise, and at five minutes post exercise. The final diastolic blood pressure was significantly lower than the initial mean. The difference in systolic blood pressure was not significant. The investigator concluded that the decrease in heart rate and diastolic blood pressure at rest, during submaximal exercise and during the recovery period indicate more efficient blood transport, less strain on the cardiovascular system and functional reserves, and an increase in submaximal work capacity.

\textsuperscript{6}Charles A. Wallin and Jack S. Schendel, "Physiological Changes in Middle-Aged Men Following a Ten-week Jogging Programme" Research Quarterly 40:3 (October 1969):600.
Six healthy male volunteers in average condition, were studied by Ekulund and Holmgren\(^7\) during 60 minutes of exercise in the sitting position. Exercise intensity for each subject was selected such that the heart rate was 140-150 after 10 minutes and 170-180 after 60 minutes. The conventional right heart catheterization technique was employed. As the exercise progressed the following results occurred. Continuously falling systemic arterial blood pressure, constant cardiac output and increasing heart rate (therefore decreasing stroke volume), as well as increasing total ventilation (both respiratory rate and tidal volume). Although progressive changes did not show in $P^H$, there was a compensated metabolic acidosis in exercise and the blood volume was lower than in the resting supine position. The authors concluded that the changes may be explained by the gravitational shift in blood volume distribution.

Massicotte, Avon and Corrivead\textsuperscript{8} investigated comparative effects of Aerobic type training on men and women. Pre and post training cardiorespiratory, muscular and blood tests revealed significant and similar increases of the maximal VO\textsubscript{2}. Oxygenated pulse, physical performance, muscular strength and resistance in both sexes, significant decreases of oxygen uptake, heart rate, ventilation, respiratory quotient, respiratory equivalent and systolic pressure at given submaximal work levels.

Holmgren\textsuperscript{9} found out in his study that Intermittent long term training resulted in an increase in physical working capacity in a steady state, total haemoglobin, and blood volume. A decrease in pulse rate was also observed. Continuous short term training also resulted in similar changes. In addition, a decrease in pulse rate in the upright position was observed following this type of training.


To study the effects of training at various heart rate intensities, Cousey\textsuperscript{10} formed a control and four experimental groups which ran a mile for four days per week for six weeks on a motor driven treadmill at different intensity levels, (60, 70, 80 and 90% of maximal heart rate level). Among the significant results were the following: (a) Resting and maximal heart rates were lowered and maximum oxygen consumption was increased when heart rates were lowered and maximum oxygen consumption was increased when heart rate intensity reached the 80 or 90% level.

Gentry\textsuperscript{11} determined the effects of nine weeks aerobic jogging programme on selected cardiovascular functions of young male college students through a time course evaluation programme. Pre test and post test administered at the end of third, sixth and ninth weeks were employed in order to evaluate the effects of training programme. He studied the


following cardio-vascular functions: resting and exercise cardiac output, cardiac index, stroke volume, stroke index, O₂ pulse, and heart rate. He concluded that there was a significant increase in resting cardiac output, resting and exercise stroke volume, resting and exercise O₂ pulse, and further observed that there was significant decrease in resting diastolic blood pressure and steady state heart rate, while no changes occurred in exercise cardiac output and resting heart rate.

In connection with the women's jogging programme at the Eugene YM-YWCA, Hilton¹² evaluated the progress of 12 married women, 27 to 58 years of age. The women jogged three mornings per week for twelve weeks with emphasis on increasing distance and time jogged rather than speed. Significant results included the following: Maximum heart rate during exercise and the recovery heart rate for each minute dropped, Oxygen consumption increased, and lung ventilation volume increased in both the resting and working

states. The mean resting heart rate dropped from 80.5 to 73.7 beats per minute. The jogging programme had little effect on diastolic and systolic blood pressures.

Hunter and Mc Carthy\(^{13}\) examined the effect of high-intensity anaerobic training on resting blood pressure and a variety of other physiological performance, and psychological variables in eight adult male competitive cyclists who trained five days a week for eight weeks in two training programmes. Resting systolic blood pressure was significantly elevated in both training programmes, and no differences were found in resting diastolic blood pressure or body weight. Significant training effects were found in both programmes for VO\(_2\) max, resting heart rate, and maximal performance on a bicycle ergometer test.

Sixteen College men were randomly divided by Sharket and Holleman\(^{14}\) into three training groups and one control group in a study of selected cardio-respiratory adaptations to six weeks of training exercise eliciting either 120, 150, or 180 heart rates. Training consisted


\(^{14}\)Brain J. Sharket and John P. Holleman, "Cardio-respiratory Adaptations to Training at Specified Intensities" *Research Quarterly* 38:4 (December 1967):74.
of walking on the motordriven treadmill for 10 minute
3 days per week. Highly significant differences were
found in the analysis of pre-post Balke treadmill test
scores. The Astrand-Ryhming nomogram for prediction of
aerobic capacity also showed highly significant changes
due to training group's improvement which was signifi-
cantly different from all other groups in both tests.
No changes were noted in resting pulse rate or in the
pulse rate - Oxygen consumption relationship. However,
there were small positive differences in the grade
required to elicit the training heart rates. The study
supports the hypothesis that intense activity is
necessary to bring about the changes associated with
cardio respiratory endurance.

Knowlton and Weber\textsuperscript{15} conducted a laboratory experi-
ment on a young female endurance runner over a period
of seventeen months of intensive training. During this
time the girl progressed from a detrained state to highly
trained condition for middle distance competition. Data

\textsuperscript{15} Ronald G. Knowlton and Herbert Weber "A Case
Study of Female Endurance Runner" \textit{Journal of Sports
was obtained at rest and during submaximal and maximal exertion and during the physiologic recovery process. Measurements included blood pressure, heart rate, haemoglobin concentration, and basal oxygen consumption. The training developed marked improvement in performances of submaximal and maximal exercise. A definite capacity to stress cardiovascular responses was developed from training as well as ability to accelerate recuperative processes. There was little change in resting haemoglobin concentration resulting from exercise but training augmented the adjusted concentration in response to work stress.

Perhaps the most consistent and pronounced change associated with training is a decreased heart rate during submaximal exercise following training. 16,17,18,19


Riner, Cureton and Boileau investigated the effects of five weeks of continuous running training at two different levels of intensity on the central circulatory (cardiac output and associated variables) and metabolic capacities, (oxygen uptake and associated variables) of fifteen 8-11 year old boys. Maximal and submaximal treadmill walking and running tests were used to evaluate circulorespiratory and central circulatory functions. Analysis of covariance revealed significant increases in Max.$\dot{VO}_{2}$ among the three groups only during the treadmill walking test. A significant decrease was found in maximal respiratory exchange ratios of the training groups compared to the control group. A significant decrease occurred with training in submaximal heart rate at a given work load only during treadmill running. The training groups showed significant decrease in submaximal respiratory exchange ratios and ventilation equivalents during a given treadmill walking load. It was concluded

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that the five week training programme at an intensity of approximately 70% or 80% max. VO₂ was generally not sufficient to produce improvement in either circulatory or central circulatory function in 8-11 year old boys.

Reindell and Roskamm 21 studied the cardiac volume of untrained subjects and well trained athletes. Their results showed that the mean heart volume in sprinters was not significantly higher than that of untrained subjects, whereas it increased regularly in middle and long distance runners as well as in professional cyclists.

Dickhuth and coworkers 22 investigated the circulatory responses of German Athletes by echocardiography and stated that decathlon athletes and power athletes have higher stroke volumes compared with untrained subjects.


because they have larger hearts due to their body weight. Of course the smallest relative heart volumes are found in power athletes and largest heart volume in endurance athletes.

Some idea of the influence of various kinds of training may be secured from a study by Bramwell and Ellis\(^{23}\) of 202 Olympic athletes. Most of these men were examined for a period of ten days preceding the various contests. The four classes of runners (Sprinters, Middle distance runners, Long distance runners and Marathon runners) who showed a decreasing frequency of pulse rate as the length of their run increased, were of special interest.

Fox and Mathews\(^{24}\) pointed out that the Maximal attainable heart rate is either unchanged or decreases slightly following training. Although the decrease in

\(^{23}\) C. Bramwell and R. Ellis, "Clinical Observations on Olympic Athletes Abeits Physiologie 2451 (1929):86.

\(^{24}\) Fox and Mathews, Physiological Basis of Physical Education and Athletics, P=314.
maximal heart rate is particularly evident in athletes engaged in endurance training, short term training of previously sedentary subjects can also cause a slight (3 to 10 beats/minute) but significant decrease in maximal heart rate.

Frick, Elovainio and Somer\(^\text{25}\) pointed out that the resting bradycardia (decreased heart rate) resulting from training is (a) most evident when athletic and non-athletic subjects are compared; (b) less evident but still clear-cut when sedentary subjects undergo a training programme and (c) least distinct when athletes are studied in the untrained versus the trained state.

Barnard, Mac Alpin, and Kattus\(^\text{26}\) discussed in their study about the decreased heart rate during sub-maximal exercise. As in the case of the resting bradycardia, this decrease is most pronounced in comparisons


of non athletic subjects and highly trained athletes. It should also be pointed out again that a slower-beating heart is more efficient, requiring less oxygen than a faster-beating heart at the same cardiac output level.

Sidhu and Grewal found out the effect of hard physical training on the cardio-vascular system of the Indian Women Hockey Players. Data were collected on 15 World Cup players. Weight and heart rate at rest, during exercise and during recovery were taken at the commencement of the training and at the completion of 25 days training. It was found that with training, the resting heart rate, and maximum heart rate after exhaustive exercise declined significantly.

The effects of training and detraining on Cardio-vascular efficiency was investigated by Kendrik, Hickman and Pollock. Twenty one men volunteers between 30 and


and 45 years of age jogged approximately eight miles per week for 20 weeks at 85% of maximum heart rate. A control group of eight sedentary men was also tested. Heart rate and blood pressure responses to a standard treadmill run (5 min, 6mph, 2.5% grade) were used to evaluate the cardio-vascular efficiency of each group, and was administered initially ($T_1$), after twenty weeks of training ($T_2$), the experimental group's heart rate improved significantly from $T_1$ to $T_2$ while that of the control group remained constant. These changes represented reductions from 10.3 to 21 beats/min. during exercise and 21 to 29 beats/min. during recovery.

Cardiovascular changes in 18 college athletes during training, compared with 15 controls were studied by Henry and they were interpreted as the result of the interplay of the basic factors, (peripheral resistance, aortic volume, elasticity, stroke volume and heart rate). The observed effects of athletic training seem to be due

to increased elasticity and resting stroke volume associated with a compensating decrease in heart rate. Brachial pulse wave tracings (Systolic amplitude) differentiate the athletes from the controls, but during training, statistically there is no change. Changes in the resting heart rate constitute a useful test of the cardiovascular aspect of athletic conditioning.

Karl stated in his study that submaximal exercises of the "endurance" type seem to have more effect on slowing down the resting pulse than maximal one of the "sprint" type.

Henderson, Haggard and Dolley in their investigation found that in the performance of the same task, the trained man's heart has the advantage of starting at a slower rate of beating; but, on the whole, it accelerates as many beats in response to the tasks as does the

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30 Peter V. Karpovich and Wayne E. Sinning, "Physiology of Muscular Activity" (Philadelphia: W.B. Sanders Company, 1971), P. 212.

heart of the untrained subjects. The pulse rate during work is slower in an athlete than in an untrained man, but the relative acceleration (expressed in per cent of resting pulse) is greater in the athlete.

Heart-rate and ventilation curves during recovery from an exhaustive walk on a treadmill were studied by Emili\(^32\) and was found to be composed of a rapid and a slow component, both exponential in character. The half time constants of the rapid components were lower in the trained than in the untrained male subject.

Kapovich and Sinning\(^33\) pointed out that the effect of training on the heart rate may be observed during physical reconditioning of convalescents. With the regaining of physical fitness, their pulse rates in response to a standard exercise gradually begin to decrease. Absence of this decrease may be interpreted as a lack of improvement or as an indication that the exercise is too strenuous.


\(^{33}\)Karpovich and Sinning, Physiology of Muscular Activity, P.280.
Fox and Mathews\textsuperscript{34} pointed out that (a) the training brady cardia is dependent upon a long time period (may be years) of intensive training and (b) the magnitude of the decrease in resting heart rate produced by training is less when the level of fitness is greater. It should also be noted that the magnitude of the resting bradycardia is the same in endurance and non endurance athletes. Apparently, neither the different training programmes, nor the different types of cardiac hypertrophy resulting from them, significantly influence the magnitude of the bradycardia.

Astrand and Rodahl\textsuperscript{35} stated that systolic pressure produces maximum pressure to overcome the resistance in the blood vessels and, thereby, produce maximum deriving force. A greater systolic pressure indicates a greater stress on the heart.

\textsuperscript{34} Fox and Mathews, The Physiological Basis of Physical Education and Athletics, P.302.

Schellong observed that systolic pressure values tend to be high immediately after exercise, while diastolic pressures are typically below resting values. During recovery, vasodilation remains until the vasomotor centres can restore normal tone in the arterioles. With the loss of resistance caused by the cessation of skeletal muscle contraction, the blood flows freely into the capillaries and the diastolic pressure drops. In ice skating and middle-distance racing, diastolic pressure has been shown to be subnormal but the value is apparently not related to the distance covered. He observed a drop in subjects after they had completed 2 runs on a 23 step stairway in 45 seconds.

Karpovich and Sinning pointed out that if exercise is very severe, the loss of the massaging action of the muscles on the veins and the high rate of blood flow into the area due to the decreased peripheral resistance after exercise may lead to excessive pooling of blood in the muscles if vasomotor

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tone is not quickly restored. This in turn will lead to a reduction in the volume of circulating blood, reducing heart output, and a decrease in systolic as well as diastolic pressure. Average systolic and diastolic blood pressure, taken within 15 seconds after all-out bicycle ergometer tests in a group of 21 subjects before and after training, were 160/64 and 162/63, the diastolic pressure showing the expected low values. Individuals within the group, however showed marked reductions in both phases. The two most extreme cases were 100/48 and 90/45. After five minutes these values increased to 114/68 and 118/60 respectively. Both subjects experienced syncope after exercise. This problem can generally be avoided if one does not stop exercise abruptly but continues to move, to keep the muscles massaging the blood back into circulation.

Bevegard, Holmgren and Johnson found out that systolic and diastolic blood pressure changes in the brachial artery, pulmonary capillaries, pulmonary artery.

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and right ventricle in athletes and non-athletes during supine exercise. The athletes were eight top flight cyclists at the beginning of their training season.

Systolic pressure rises with increase in heart rate in both athletes and non-athletes. The latter, however, do not show as large an increase for a given heart rate. The brachial artery pressure shows rather substantial changes, upto $211.1 + 28.1$ mm Hg during sitting exercise. This is apparently related to the higher stroke volume found in athletes.

Pressures on the pulmonary side of the circulation do not show as much change as those on the systemic side. This serves a useful purpose as extreme pressures in the lungs would result in the diffusion of water from the blood to the alveoli.

Guyton\textsuperscript{39} pointed out that the pulmonary arterioles

are passive and that they expand with pressure, offering little resistance to the passage of blood, and thereby reduce the load on the heart.

The circulatory studies conducted by Bevegard, Holmgren and Johnson\textsuperscript{40} revealed that the changes in diastolic pressure tend to be quite small compared to the systolic changes. Values shown for athletes at rest, low work load, and high work load are $68 \pm 7.1$, $73.5 \pm 5.6$, and $84.6 \pm 7.3$ mm.Hg. This observation is even more strongly supported by data taken in the sitting position, where the respective values were $81.3 \pm 11.7$, $83.0 \pm 8$, and $87 \pm 11.6$ mm.Hg.

Charles, Mathes and Bedford\textsuperscript{41} evaluated the response of non-trained and endurance trained rats to


conditions of lower body negative pressure (LBNP) and concluded that endurance training will be associated with greater decreases in arterial blood pressure during LBNP compared to non-trained populations.

Congswell, Hinderson and Berryman\textsuperscript{42} indicated that there is a tendency to decrease the systolic blood pressure of the trained group.

The statement made by Dawson\textsuperscript{43} more than 60 years ago that the effects of training on the resting blood pressure are neither striking nor constant still seems to hold true.

According to Cruchet and Moulinier\textsuperscript{44} during steadystate work, the systolic blood pressure may rise


\textsuperscript{43}P.M.Dawson, The Physiology of Physical Education (Baltimore: Williams and Wilkins Company, 1935), P-215.

\textsuperscript{44}R.Cruchet and R.Moulinier, Air Sickness (New York: William Wood and Company, 1920), P-355.
and remain more or less constant. In fatigue, however, the person unadapted to exertion may show a drop to below resting level.

A study on 202 Olympic athletes by Bramwell and Ellis showed that Olympic athletes have systolic, diastolic, and pulse pressures within the range common to people of similar ages.

Ekblom and Hermansen reported that haemoglobin concentrations at rest do not usually change with training. If anything, it decreases slightly. For example, the normal haemoglobin concentration for males is 15 grams per 100 ml of blood on the average. In a group of highly trained endurance runners, the average haemoglobin concentration was only 14.3 gm/100 ml blood.

Rampotti is of the opinion that endurance from

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45 Bramwell and Ellis, *Arbeits Physiology*, P. 51.


47 Kelevi Rampotti, "The Blood Picture as a Guid to Training" *Track Technique* (September 1960): 36.
physiological point of view is a question of body's ability to absorb Oxygen. Haemoglobin value, therefore, is of great importance in athletic performance.

Pilch\textsuperscript{48} studied the cardiovascular responses of selected middle aged subjects to regular periods of exercises. Haemoglobin was one of the selected variables. The experimental group pedalled the bicycle ergometer thirty minutes per day for four days per week, for six weeks at a work load that kept the heart-rate at one hundred and thirty-five beats per minute. There was no significant change in haemoglobin content from pre to post training on the experimental group.

According to Devaries\textsuperscript{49}, physical conditioning can increase the total haemoglobin as a result of the increased blood volume, but there will be no increase in haemoglobin concentration per unit volume.

\textsuperscript{48}A. H. Pilch, "Cardiovascular Responses of Selected Middle Aged Subjects to Regular Periods of Exercise" Dissertation Abstracts International 32:2 (August 1971): 775A.

Stephens\textsuperscript{50} studied the effect of isotonic and isometric exercises on selected physiological variables. Haemoglobin concentration being one of them. No significant increases in haemoglobin concentration were observed under exercise conditions. But isotonic conditions resulted in greater haemoglobin concentration which was observed under exercise conditions.

Corder\textsuperscript{51} studied the acute and chronic effects of isometric exercise on selected haematologic measures of which haemoglobin concentration was one of the variables. Blood samples were analysed during the fourth and sixth weeks, after the training period. No significant differences were observed between the three kinds of isometric exercises.

\textsuperscript{50} Martha Stephens, "A Study of the Effects of Isotonic and Isometric Exercise on Selected Physiological Variables" Completed Research in Health, Physical Education and Recreation 7 (1976):70.

Holmgren and others in their study concluded that intermittent long term training resulted in significant increase in haemoglobin concentration. Analysis of data also revealed significant increase in haemoglobin as a result of continuous short term training involving skiing every day for eight to ten days.

Cullumbine has studied the correlation between blood haemoglobin concentration and response to various exercise test for subjects aged 10 to 20 years. It was concluded that the haemoglobin concentration was significantly correlated with speed of movement, strength and ability to sustain prolonged moderate muscular effort. There was no evidence for a significant correlation between the haemoglobin level and the response to either moderate to severe exercise. He believes that this severe type of exercise was too severe, that the Oxygen dept was


too large to be influenced significantly by the rather small range of haemoglobin levels present in this group of subjects.

Boorthby and Berry\textsuperscript{54} in studying the effects of work on the percentage of haemoglobin and the number of red blood cells cited as findings 43 percent increase of leucocytes in soldiers after marching.

A review of the first 15,000 field and clinic tests by Hyman\textsuperscript{55} showed that nearly all well-conditioned athletes score 1.000 and above in the adynamic stage of the C-P Index; many reach as high as 1.500. The highest known score of 1.825 was made by one of the 1964 Olympic contestants. Nonathletic but normal students score from .800 to .900. This stands in marked contrast to patients with heart disease and/or pulmonary conditions, where scores as low as .348 had been found at bed rest.

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\textsuperscript{54}Walter M. Boorthby, and Frank B Berry, "The Effect of Work on the Percentage of Haemoglobin and Number of Red Corpuscles in the Blood" \textit{American Journal of Physiology} 37 (1915): 378.

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Hyman considers a C-P Index of 1.000 to represent a normal resting functional capacity level for the age periods between 16 and 60. Many well-conditioned athletes present C-P Index scores of 1.5 and over. The average athlete of college level scores from .9000 to 1.150, while high school boys range from .700 to .950.

Hyman through his experience in clinic and field tests claimed that well-conditioned athletes show a drop of 1 to 5.5 percent; in certain instances there has been an actual rise in C-P Index (Dynamic). Non-athletic but normal students with poor physical fitness show a drop of 15-30 percent in the C-P Index (Dynamic). Cardiac cases show the greatest drop after exercise; this usually extends from 35 to 65 percent.

So far, we had discussed cardio-respiratory changes resulting from training that are concerned mainly

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56 Ibid.

with circulatory functions. Now the reviews of several respiratory changes that appear to be as a result of physical training is presented.

Karpovich and Sinning\(^{58}\) explained that training brings about well defined changes in the respiratory mechanism and its functioning. The expansion of the chest is increased; the rate of breathing is slowed and its depth is augmented. In sedentary individuals, large portion of the lungs may be physiologically closed off from the air inhaled; while, with training the entire lung volume easily becomes available exposing the blood to oxygen over as much as 100 square meters of surface, instead of a fraction there of.

Dunwoody and Rhodes\(^{59}\) tried to compare certain respiratory exchange variables between three groups, aerobic (Ae), anaerobic (An) and untrained (Un), at their

\(^{58}\)Karpovich and Sinning, \textit{Physiology of Muscular Activity}, P.161.

aerobic thresholds (AT), maximal aerobic and anaerobic capacities. Thirty College aged males, ten per group, were tested on two different treadmill protocols to elicit the running velocity at the threshold of anaerobic metabolism (Vt an), VO₂ max. and maximal anaerobic capacity from the anaerobic speed Test (A.S.T.). Significant differences between the three groups were found for VO₂ max. No significant difference in excess CO₂ elimination at VO₂ max. was evident among the three groups although the Un group demonstrated significantly higher values when compared to the An group at the AT (Un: 9.26, AN: 6.31, Ae: 8.03 ml/kg-min). Significant differences were also demonstrated between the three groups for anaerobic capacity in the A.S.T. (An: 85, Ae: 63.6, Un: 39.5 seconds). The peak excess CO₂ eliminated values from the A.S.T. was higher for the AN and Ae group when compared with Un group.

Martin, Chen and Kolka\(^{60}\) conducted a study about anaerobic metabolism of the respiratory muscles during exercise and summarised that although minute ventilation (VE) exhibits marked increases during heavy rhythmic

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exercise utilizing a large muscle mass, the extent to which this hyperpnea stresses the respiratory muscles remains controversial. In an attempt to resolve this matter they measured arterial blood lactate concentration during seated isocapnic reproduction of peak exercise ventilation. They found that maintenance of peak exercise ventilation raised blood lactate 50% in subjects otherwise at rest. This lactate rise occurred despite addition of CO₂ to inspired gas in amounts sufficient to maintain arterial blood pH and P CO₂ at resting levels, which suggest that achieving the high exercise ventilation associated with VO₂ max. may require significant anaerobic metabolism by respiratory muscles.

Hagberg et.al.;61 undertook the study to evaluate the effects of endurance exercise training on O₂ deficit on the time course of the adjustment to and recovery from submaximal exercise of Oxygen uptake (VO₂), Carbondioxide

production (VCO₂), minute ventilation (VE) and heart rate (HR). It was found that O₂ deficit and O₂ debit were lower at the same absolute workrate after training. The increase in VO₂, VCO₂, VE and HR at the onset of constant load, submaximal work and the decrease in VO₂, VCO₂, VE and HR in recovery were more rapid at both the same absolute and same relative work rates after training. He concluded that the adaptation to endurance exercise training enabled an individual to adjust to the energy requirements of constant load of submaximal work more rapidly, resulting in smaller O₂ dept. The rate of recovery is also more rapid after training, resulting in a smaller O₂ dept.

At a submaximal exercise regimen, Flint, Barbara and Steven⁶² utilized heart rate to assess training effects on walking on a motor-driven treadmill for six weeks, three times per week, 30 minutes each session,

at a constant speed of 90 meters per minute. The training heart rate was monitored at 75 to 80% maximum by adjusting the slope of the treadmill. Training effects were determined by responses to a submaximal work load of 70% of max. $\text{VO}_2$ and by the increase in predicted max. $\text{VO}_2$ following training. Oxygen intake during the non steady state of submaximal work became significantly higher after training, although steady state values remained unchanged. Heart rate, oxygen pulse, respiratory exchange ratio, and excess carbon dioxide production all showed significant training effects. No changes were noted in respiratory minute volume, respiration rate, ventilation efficiency, and systolic and diastolic blood pressures.

In their study of 110 boys, aged 10-17 years, Morse, Schlutz, and Cassels$^{63}$ found that the maximal lung ventilation per minute was constant for the different age groups (1.6 litres per minute and per Kg); but in the

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$^{63}$M. Morse, F. Schlutz, and D. Cassels, "Relation of Age to Physiological Responses of the Older Boys to Exercise" Journal of Applied Physiology 1 (1949):683.
older boys it was attained with fewer respirations by increasing the ratio of tidal air to vital capacity. The respiratory rate for the youngest group was 60 per minute. Tidal air in relation to vital capacity was 47.5 per cent. Corresponding values for the oldest subjects were 53 per minute and 55 per cent, respectively.

Astrand\textsuperscript{64} showed that the ventilation at submaximal working intensities increased almost linearly with oxygen intake. During maximal work it shows a relatively larger increase. The tidal air during work within certain limits is quite independent of the size of ventilation, and reaches 40-60 per cent of the vital capacity (the "optimal" tidal air).

Karpovich and Sinning\textsuperscript{65} stated that the trained man breathes more economically than the untrained. For the same task, he needs less air because he can utilize

\textsuperscript{64}Per Olof Astrand, "Experimental Studies of Physical Working Capacity in Relation to Sex and Age" (Ejnar Munksgaard: Copenhagen, 1952), P.72.

\textsuperscript{65}Karpovich, and Sinning, Physiology of Muscular Activity, P.161.
a greater portion of its oxygen than an untrained one. This difference becomes pronounced when heavy loads of work are carried. The effect of training shows itself so gradually that only after weeks may a slight evidence be observed. The maximum, however, may be reached after seven weeks of training.

Tabour attempted to describe the effects of training at a constant work load upon minute volume of breathing (V), respiratory frequency (f) and tidal volume (Vt), and to relate these to changes in heart rate blood lactate levels and Oxygen uptake. Six subjects trained three days per week on a motor driven treadmill at a pre-determined work intensity. The near-maximum training load remained constant through six weeks of the study, then was increased for three of the subjects for six more weeks. Each subject was tested weekly during one of the training sessions and the data were collected. The results showed marked decrease in both V and F between the first

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and second trials. In subsequent trials, smaller but progressive decreases were seen in these two variables. Tidal volume tended to increase with training but the results were somewhat less clear. Changes in VO₂ did not accompany the above responses, whereas heart rate and blood lactate level changes were seen closely related to the changes in V and F.

Interval training consisting of ten 100 meter runs in 15 sec. on a cinder track was experimented in students by Ardison. Transposition to the vertical bicycle ergometer was obtained with the repetition of 10x 1558 Kpm loads during one minute with an initial heart beat of 120/min, representing an energy outlay of about 40-50% of each subject’s maximum potential. Parameter patterns during the first loads were those of the classic adaptation period in continuous work. Maximum and minimum minute ventilation, cardiac frequency and Oxygen pulse

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values were observed during loading and resting respectively, while the respiratory equivalent ratio was highest during resting period. A second set of tests after some months was used to assess the effects of training in a comparative study of minute ventilation and heart frequency. The results were directly opposite to those reported by other workers and were discussed in the light of differences in position on the ergometer. Interval training is marked by the search for equilibrium that is never achieved. Payment of the Oxygen debt also evolves in an intermittent fashion.

Cureton conducted a study on fifteen men, averaging 40.2 years of age, who ran a cross-country course at the University of Illinois for 5 months, four or five times per week. The total distance was 3.5 miles. The improvement in "peak oxygen intake showed a statistically significant difference greater than the .01 level.

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Other significant changes were in maximum pulmonary ventilation and in maximal oxygen pulse.

Pollock et al.;^69^ determined the effects of training 45 minutes 2 days per week, at varied intensities, on Physiological measures of middle aged men. Twenty two men of average age 38.7 years were randomly assigned to one of the two experimental groups. Group I trained at 90% of maximal heart rate and group II at 80% for a total of 20 weeks. Twelve controls of (Group III) similar qualifications were also evaluated. Exercise sessions were closely monitored on a quarter mile track with total distance trained being equal for both groups. Intensity was estimated by the palpation technique (beats/10s) at 15, 30 and 45 minutes of training. Training results showed both experimental groups improved significantly in Cardiovascular function, while spirometry measures remained relatively constant. This was shown by increased max.\(\text{VO}_2\) Max.\(\text{VE}\) and Max.\(\text{O}_2\) pulse.

Fox and Mathews pointed out that (1) maximal minute ventilation is increased following training. Since ventilation is not a limiting factor for the max. V0₂, the increase in maximal ventilation should be considered secondary to the increase in max. V0₂. Nevertheless, the increase is brought about by increase in both tidal volume and breathing frequency.

(2) Training causes an increased ventilatory efficiency. A higher ventilatory efficiency means that the amount of air ventilated at the same oxygen consumption level is lower than in untrained individuals. Since the Oxygen cost of ventilation increases greatly with increasing ventilation a greater ventilatory efficiency, particularly over a prolonged effort would result in less oxygen to the respiratory muscles and more to the working skeletal muscles.

(3) The various lung volumes measured under resting conditions (with the exception of tidal volume)

70 Fox and Mathews, Physiological Basis of Physical Education and Athletics, PP. 316-317.
are larger in trained than in untrained individuals.

The observations made by Douglas and Haldane showed that, during severe exercise, lactic acid rapidly accumulates in the body. In intense muscular effort it may be set free at the rate of about 3 gm. per second. While lactic acid is accumulating in the blood, a certain amount of carbon dioxide will be displaced from its combination with bicarbonate and driven off from the blood. The increase in H+ ion concentration, however, more than offsets the inhibitory effect of the decreased carbon dioxide tension upon the respiratory ventilation, and the sum total of the partial effects increases. The total lung ventilation increases. When there was an increase in speed of walking, from 4 to 5 miles per hour, lung ventilation rose, in spite of a drop in carbon dioxide tension in the alveolar air, because of a possible rise in the lactic acid content of the blood and an increased intensity of reflexes from the muscles.

Ewing, et al., examined the relative effects of

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treadmill training at either 50 or 65 percent of the heart rate reserve added to the resting heart rate for 27 sedentary college women. All subjects trained at the desired heart rate three times weekly for nine weeks with the duration of each session limited to the time required to elicit 1,000 excess heart beats above the resting level. There was a significant increase for Oxygen pulse, and pulmonary ventilation. Significant decrease was observed for ventilation equivalent and heart rate response to the standard work load of 300 Kpm/min.

Bonen, Gass and Heyward examined in three conditioned young men, the changes in submaximal cardio-respiratory parameters during an 8 week training period of treadmill running. Training sessions were conducted in alternate days, three days per week. Each session consisted of a 5 minute warm-up walk at 3.7 mph, followed by a 30 minute run at 6.3 mph (=65% VO₂ max.) and a five minute recovery walk at 3.7 mph. The treadmill was maintained at 0% grade. Throughout the 40 minute exercise

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period VE and breathing rate were continuously recorded. Expired air was sampled over each 5 minute period and heart rate was recorded during the last 15 seconds of each 5 minute period. Throughout the training period, the oxygen cost and the respiratory rate remained unchanged. It was observed that the VE, heart rate and breathing rate decreased progressively for a given 5 minute period of the run throughout the 8 weeks of training. The same parameters decreased throughout the 30 minute run when the first week of training was compared to subsequent weeks. These patterns indicated that cardiac adaptation to exercise was progressively enhanced and there was a small shift toward fat metabolism. Comparisons of maximum \( VO_2 \cdot VE \) and heart rate before and after training revealed that the maximum \( VO_2 \) was increased but no changes was observed in the maximum VE and heart rate.

Dolgener and Brooks\( ^74 \) determined the effects of

\[\text{\footnotesize \cite{74} Forest A Dolgener, and Wayne B. Brooks, "The Effects of Interval and Continuous Training on VO}_2 \text{ max. and Performance in the Mile Run" Journal of Sport Medicine and Physical Fitness 18:4 (December 1978):345.}\]
an interval and continuous training programme on mile run performance and \( V_O_2 \) max. and found that the interval training group demonstrated significant increases in \( V_O_2 \) max. VE and total time on the bicycle and significant decreases in percent body fat, resting heart rate and mile run time.

According to Fox and Mathews\(^{75}\) in untrained men and women, where \( V_O_2 \), \( V_CO_2 \), and working capacities are lower, max. VE is also lower. Along with this lower max. VE is a lower ventilatory efficiency, i.e., untrained men and women have a greater VE at a given \( V_O_2 \) than trained men and women.

Dejoueurs\(^{76}\) expressed that ventilation not only varies with work load, but it also varies before, during, and after exercise at any given work load.

\(^{75}\)Fox and Mathews, *Physiological Basis of Physical Education and Athletics*, P.134.

Davis in his study expressed that a faster and more comfortable way to detect the anaerobic threshold is by observing the minute ventilation and other gas exchange variables, such as carbon dioxide production, during a progressive exercise test. These variables increase linearly, i.e., in a straight line fashion, with increasing workloads until the anaerobic threshold is reached. At this point, their rate of increase is greatly accelerated.

"Trained individuals have a higher ventilatory efficiency than untrained persons. A higher ventilatory efficiency means that the amount of air ventilated at the same oxygen consumption level is lower. The oxygen cost of the ventilation increases greatly with increasing ventilation. Therefore, a lower ventilation, particularly over a prolonged effort (e.g. the Marathon), would mean less oxygen to the respiratory muscles and more to the

working skeletal muscles". 78

"The greater the learning factor involved in exercise, the greater the reduction in minute-volume after training. Therefore, the smallest change will be observed in walking, but there will be considerable change in ice skating and, especially, in swimming. For example, in the crawl stroke at 2.5 feet per second, a trained swimmer may have a minute volume five times smaller than that of a beginner". 79

It seems clear, therefore, that the trained man ventilates his lungs, both during rest (although this difference may disappear under basal conditions) and in exercise, more economically than does the untrained. This is particularly advantageous during exercise for exertion that causes an increased utilization of oxygen without an exorbitant increase in the minute-volume of breathing". 80

78 Fox and Mathews, Physiological Basis of Physical Education and Athletics, P.197.

79 Karpovich and Sinning, Physiology of Muscular Activity, P.162.

80 Ibid.
After exertion, the untrained man will often breathe in the "Cheyne-stokes" manner. Individual breaths wane and then increase in rhythmic fashion. This condition, however, is absent in physically well-trained men.\(^{81}\)

Besides causing more efficient respiration, training increases the endurance of the respiratory muscles. A feeling of discomfort and tightness around the chest, experienced by the untrained, is greatly reduced and may be absent in the trained person.\(^{82}\)

Because coaches have used the HR of 180 beats per minute as a guide for training males, Guillians\(^{83}\) in his study wanted to establish its applicability for women of two training levels. Twelve subjects, six middle distance runners on an year around training programme and six physical education majors, four on varsity

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\(^{81}\)Ibid.

\(^{82}\)Ibid.

teams with little training or no training restrictions, participated in this study. It was found that there were only two variables, ventilation and lactic acid accumulation, which are shown to be significantly different between groups. Ventilation for the trained group was significantly lower (P.01) than for the major group, whereas oxygen consumption was the same in both groups. Lactic acid was significantly less (P.01) for the trained group; the major groups produced 66 percent more lactic acid. Work performance, time to reach a HR of 180 beats per minute, VO₂, R, and Oxygen pulse (VO₂/HR) were not significantly different between the trained and Major groups.

Schneider investigated step by step, the changes in the gaseous metabolism and breathing that occur during and after a period of daily indulgence in a moderate amount of Physical exercise and found that the trained man breathes much less air for the same accomplishment.

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than does the untrained subject they also found that a moderate amount of daily exercise reduces the amount of air inhaled during a period of work. The change was brought about so gradually that it was impossible to determine just when it begin, but it was slightly in evidence by the end of the second week of training. The maximum reduction was reached from four to six weeks.

The reduction in the minute-volume of breathing was fairly large, but was most conspicuous with heavy loads of work. The younger of their subjects showed as a result of training, a reduction of about 15 percent for a load of 4000 ft. lbs.; his average minute volume before training was 32.4 liters and during training 27.6 liters. With a load of 8000 ft. lbs. this subject breathed 17 percent less air when in training than when out of training. He averaged 56.5 liters per minute before training and 46.9 liters when in training. Their older subject showed even a greater change. With a load of 4000 ft. lbs. he at first breathed 36.2 liters per minute and during the last part of the training period only 30.1 liters. Training therefore, for this load
brought about a reduction of 16.6 percent in the volume of air breathed. With a load of 6000 ft. lbs. the reduction amounted to 23.3 per cent; from an early average of 46.3 liters it was lowered to 35.5 liters in the late training period.

Schneider and Ring\textsuperscript{85} in one of their experiment on two subjects found that the minute-volume of pulmonary ventilation decreased by 15 to 23.5 percent, while absorption of oxygen increased by 12.0 to 16.5 percent. No wonder that the same work was performed more easily after training. When subjects discontinued their training, they were practically back to a pre-training condition in four weeks.

Emili, Petit and Deroanne\textsuperscript{86} were performed Experiments on seven untrained and seven well trained healthy


male students. The subjects exercised on a bicycle ergometer at varying work loads while respiratory measurements were recorded. Training did not effect the mechanical work of breathing at various ventilation levels. At maximal levels in these experiments the load amounted to 60-209 cal/min. Ventilatory capacity does not represent a limit to pulmonary ventilation. At any given metabolic level, the mechanical work of breathing is smaller in trained men. This is due to essentially to the lower ventilation required for any given oxygen uptake by trained subjects. The mechanical efficiency of breathing is about 0.2. At any metabolic level the oxygen cost of respiration is smaller in trained than in untrained individuals.

Mostyn et.al.; has been found that champion swimmers have a higher pulmonary diffusion capacity during the steady state than normal subjects of the same age or long-distance runners. Whether this is due to training

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or to the innate characteristics of the men is impossible to tell.

Asmussen and Nielsen\textsuperscript{88} stated that the ventilation increases in relation to the oxygen intake more during exhausting work than during light work. An important cause is that the blood during heavy work contains specific substances which are produced under anaerobic conditions in the working muscles, and which have a pronounced stimulative effect on the ventilation. It is also probable that the feeling of stress, while doing maximal work, gives an increase of ventilation.

Gordon, Levine and Wilmaers\textsuperscript{89} found that marathon runners had only an average vital capacity, which indicates that prolonged vigorous training does not necessarily increase the breathing space of the lungs. They found no important relationship between the vital capacity of the lungs and the order in which the runners


finished a 25-mile race.

"Maximal minute ventilation is increased following training. Since ventilation is not a limiting factor for the Max VO₂, the increase in maximal ventilation should be considered secondary to the increase in Max VO₂. Nevertheless, the increase is brought about by increase in both tidal volume and breathing frequency."\(^{90}\)

"An adequate supply of Oxygen is necessary for normal life and activity. It is used by all the cells for oxidative processes in the metabolic changes from which energy is derived. Whenever more energy is required, metabolism is increased, and hence the need for oxygen is also increased."\(^{91}\)

"It is important to realize that man particularly lives a hand-to-mouth existence as far as his oxygen supply is concerned. There is, however a certain amount of oxygen present in the body, only a small part of which

\(^{90}\) Fox and Mathews, *Physiological Basis of Physical Education and Athletics*, P. 315.

\(^{91}\) Karpovich and Sinning, *Physiology of Muscular Activity*, P. 90.
can be used in an emergency. This is the oxygen found in the blood and in the lungs, the total amount being between 1800 and 2250 cc. An additional 40 to 400 cc. may be present in combination with myoglobin. 92

When at rest, the body requires from 200 to 300 cc. of oxygen each minute. In vigorous exertion this need may be increased more than 20 times. Since muscles constitute about 40 percent of the body weight, their consumption of oxygen may increase at least 50 times. 93

Oxygen intake, during exercise, can be increased up to the maximum rate of oxygen consumption, which is referred to as the maximum oxygen intake or aerobic power. 94

According to Saltin and Astrand 95 the oxygen intake during a given exercise depends on the intensity

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92 Ibid.
93 Ibid., P.91.
94 Ibid.
of work and the size of the muscle groups involved. Well trained athletes are typified by high maximum oxygen intakes, the highest values being recorded for those who participated in endurance activities. The highest value relative to body weight was 85.1 milli litres per kilogram per minute in a cross-country skier, while the highest absolute value, 6.17 liters per minute, was found in a participant in orienteering.

Conley et al. 96 conducted a study on the U.S. record holder for the mile, Steve Scott on physiological changes accompanying training and found that Steve Scott, American record holder in the mile, experienced an 8% increase in VO₂ max. and a 5% improvement in running economy from offseason to peak-season conditioning. Among those characteristics measured the essential difference between Scott and the former American record

holder in the mile, appeared to be running economy, which may have allowed Scott to perform a standard work load at a smaller percentage of his maximal aerobic capacity.

Oxygen consumption, heart rate, and blood flow in athletes and nonathletes trained and untrained, after exercise was studied by Robert and Lorens. Oxygen consumption before, during and after exercise was the same for all the subjects, regardless of training. The heart rate of nonathletes was significantly higher and slower in returning to control levels. Training results in a smaller displacement of organism from Physiological equilibrium during exercise. Perhaps the circulatory displacement is reduced in athletes because of improved muscle perfusion.

Girandola tried to determine the quantitative changes in oxygen consumption during exercise and recovery

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during submaximal work following a period of physical training. Thirty three college men underwent 10 weeks of endurance-type training; an equal number served as controls. The work task was 10-minute ride on a bicycle ergometer at a standard load of 1080 kpm/min. Min-by-Min VO$_2$ values were obtained during the exercise and for 15 minutes of recovery. The same test was administered following training. The total gross oxygen consumption for the control group for test 1 was 24.675 liters during exercise and 9.396 liters during recovery. The values for the test 11 were 24.703 and 9.518 liters during exercise and recovery, respectively. It was concluded that a programme of endurance type training will result in a decrease in the Oxygen deficit and also a decrease in the lactate proton of the Oxygen debt.

It is most impressive to see the importance in oxygen intake in middle-aged men, but it only verified what has been known to be true, i.e., there is a high relationship between the endurance runs of a mile or more and the aerobic oxygen intake "peak" capacity. It appears that the longer the run, the higher the
relationship is, because the "steady state" is developed and the men run without developing an oxygen debt, except probably at the finish if they sprint for the finish line.  

Sjodin and Jacobs\textsuperscript{100} evaluate the longitudinal effects of endurance training on aerobic power. The oxygen cost of running and the lactate response to submaximal exercise, 8 boys who train and compete in running have been examined every six months since the fall 1978 when mean age was 13 years. The following variables were determined in the laboratory in each test occasion maximal aerobic power (\(\text{VO}_2\, \text{Max.}\)), Oxygen consumption while running at 15 KM x h\(^{-1}\) (\(\text{VO}_2\, 15\)), \(\text{VO}_2\) max. increased both in absolute values and when expressed relative to body weight, while \(\text{VO}_2\) decreased both absolutely and relative to \(\text{VO}_2\) max.

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\textsuperscript{99} Cureton, The Physiological Effects of Exercise Programmes on Adults, P.88.

\textsuperscript{100} B. Sjodin and I. Jacobs, "\(\text{VO}_2\) max; Oxygen Cost of Running and Lactate Response to Submaximal Exercise After 4 years Endurance Training" Medicine and Science in Sports and Exercise 14:2 (1982):104.
Burke and Franks,\textsuperscript{101} were determined the effects of different training intensities on VO$_2$ max. Sixteen males (ages 16–18) were randomly assigned to 1 of 3 training groups or a control group. The training groups trained 3 days/wk on bicycle ergometers at different intensities (85%, 75% or 65% of HR max) with all groups doing the same total mechanical work (12,000 Kpm per training session). Measurement of VO$_2$ at each of the 3 work loads in 2 anthropometrically similar individuals revealed a similar VO$_2$ cost needed to accomplish 12,000 Kpm of mechanical work. Analysis of covariance revealed a significant differences were found between both the 85% and 75% groups and the control.

Eugene and Eugener\textsuperscript{102} investigated the effects of exercise on central blood volume of ten minutes of moderately heavy long exercise in ten normal male subjects and found that Oxygen consumption and cardiac index increased


during exercise.

An investigation was to identify and to measure the specific effects of three forms of anaerobic training was conducted by Mcartor. Interest was centered on the different effects of the anaerobic training programmes and the variations in effects between anaerobic and aerobic training and measured by mean gain scores for the variables. Oxygen consumption, oxygen dept, Maximal blood Lactate concentration, and five components of work intensity. Twenty three subject was randomly assigned to one of four training designation: Alactacid, Lactacid, Alactacid + Lactacid, Alactacid + Lactacid, or Aerobic.

Following the pretest, the subjects engaged in a three day per week training programme for a period of six weeks. During each training session, the subjects received intermittent work and rest periods, whose

duration and intensity were determined by the training group protocol. The post test was administered following completion of the training treatments. Based upon the statistical results, the following major conclusions were justified.

1. A mechanism of energy output need not be stressed in order to produce significant improvements, although the amount of improvement for an energy output mechanism may be directly associated.

2. Training programmes which concentrate on the development of aerobic power, the alactacid power, the lactacid power, or the alactacid plus lactacid power will each increase the capabilities for the anaerobic power energy output, although specific training programmes may not differ significant in their abilities to develop specific components of anaerobic power.