Chapter I

INTRODUCTION

The growth of civilization is closely linked with physical fitness. In the early stages, survival of an individual depended upon his level of physical fitness. In primitive societies the hunters had to face the raw forces of nature without any protective armour, the wild beasts whom they could not match in strength, speed and similarly other enemy tribes. They could survive only if they possessed a high level of fitness.

Next stage was the urban. When man became a producer of food, he settled down in congenial surroundings and built his cities, developed productive skills and embarked upon a journey towards a better life. At that stage a few settled civilizations were surrounded by a much larger population of uncivilized, savage groups who preyed upon these more advanced people. For a number of centuries more civilized but somewhat softer communities bore the brunt of the aggression of these fitter but savage cousins. The march of civilization was somewhat bloody; the savages defeated and dominated the civilized
and through this contact became civilized to be eventually attacked by those who were still uncivilized but more fit and aggressive. This establishes the link between physical fitness and military preparations which survives till today.

Daily living in modern society brings in many problems and labour saving tendency has now reduced the physical activity to a minimum. The biological effect of inactivity is only partly understood but all agree that urbanised man is in danger and that the state of involvement of the skeletal muscle has certain secondary effects on the central and peripheral circulation as well as some unsettled physical conditions. The physical activity in different professions has decreased rapidly and this fact combined with the consequences of the impact of motorizing has diminished the cardiac need. At the same time an increased supply of food has become available and as a rule we do not respond to diminished physical activity by a corresponding decrease in calorie intake. Sports activity or physical education is certainly essential in modern society as a compensation for the diminished physical activity.
Now-a-days there is a general awakening among the physical education teachers, coaches and the trainees to the concept of optimum fitness for competitive participation and preventive maintenance of his body and especially of his heart, which assures a long and healthy life.

For one to contribute to the best of one's ability to all aspects of physical education and athletics will require a good understanding of the available scientific knowledge and has to improve through scientific research. Not only will such understanding result in better teams and better programmes of activities but it will also enable one to guard the health of one's students and athletes, which is one of the primary responsibilities of a physical educator or a coach. Then too, knowing the reasons why one select a particular approach for accomplishing a specific task immediately establishes one as a professional person rather than a mere technician.¹

Therefore, today more than ever before, it is necessary for the physical educator and coach to recognize the vital

part that science plays in the successful conduct of physical education and athletic programmes. Exercise physiology is playing a vital part in this. Over the past twenty five years the number of exercise physiology laboratories has increased tremendously. As a result much more new information about how best to train athletic teams and to develop fitness for health has appeared in the scientific literature. But in India this field is far from expectation. So the present study was undertaken to rectify this defect.

Physical exercise is an activity in which every human-being engages to one degree or another, during the course of his life. It is of the utmost importance to know the physiological mechanism that sustains and acts as the basis of every body response to exercise. In the course of physical exertion, a number of co-ordinated and compensatory adjustments take place throughout the body, which involve metabolic functions and the nervous, muscular, circulatory and respiratory systems. Important roles are played by environmental conditions, stress, training and fatigue. 

2Laurence E. Morehouse and Augustus T. Miller, Physiology of Exercise (Saint Louis: The C. V. Mosby Co; 1971), P.5.
Competitive sports make tremendous demand on the physical condition, physical fitness, and mental power of the participant. Only athletes or sportsmen or women in the finest condition may withstand the wear and tear of competitive season. Only the fittest can play to the best of his ability.

In the early years of development of training each trainer had his own "secrets" and each new champion was supposed to have discovered a new magic formula. It was the common practice to attach great importance to the idiosyncrasies of successful athletes. Early techniques and training methods were nearly all invented by athletes but now exercise training is considered as a form of science. The success of different training methods are usually evaluated by their biologic adaptations in order to improve performance in a specific task. The modern coach is always in the look out for new ideas relating to any phase of his work. There is a marked contrast to the earlier style of training in which each coach had his open system which every one of his athletes followed. Coaches still have systems which are characterized by the attitude they allowed for variation according to the
needs of the individual. Therefore, a variety of training methods are in use in the modern world of Sports.

All along the evolutionary changes there have been influences contributing to the current state of training knowledge for developing cardio-respiratory endurance. The basic methods of training have not changed much, but they have been put into more scientific based systems that involve higher quality, more quantity and regular and prolonged application. The methods such as aerobic and anaerobic, was perhaps the most alluring discovery since the beginning of the century in the realm of training.

The quantity of a load on the body depends on the inter-relation and balance of the load characteristics. These determine the physiological effects and bring about a specific training effect. There are also close inter-relationships between the different load characteristics. This dependance of the load characteristics on one another is reflected in the basic methods.

Usually sports coaches such as basketball or soccer place considerable importance on the development of cardiovascular or aerobic capacity and devote little time to
various phases of vigorous anaerobic conditioning. It is true that these sports require a relatively steady release of aerobic energy. However, in those crucial situations that demand all-out effort, if the relative capacity of the athlete's anaerobic energy transfer system is poor, the player will be unable to perform at full potential. Training the anaerobic capacity of endurance athletes, on the other hand would be wasteful because the contribution of anaerobic energy to successful performance is minimal. Rather, these activities demand a well-conditioned heart and vascular system capable of circulating large quantities of blood as well as high capacity of muscle cells to generate A.T.P. aerobically. At the other extreme, one's capacity for aerobic metabolism contribute little to overall success, like in sprint activities and throws or power lifting. Here performance is largely dependent on muscular strength and power where energy is generated primarily from reactions that do not utilize Oxygen. ³

Most sports activities require a moderately intense yet sustained energy release. This energy is provided by the aerobic breakdown of carbohydrates, fats and proteins. Unless a steady rate can be achieved between oxidative phosphorylation and the energy requirements of the activity, an aerobic-anaerobic energy imbalance develops, lactic acid accumulates, tissue acidity increases, and fatigue quickly ensues. The ability to sustain a high level of physical activity without undue fatigue depends on two factors. (1) The capacity and integration of the various physiologic systems for oxygen delivery, and (2) the capacity of the specific muscle cells to generate ATP aerobically.\textsuperscript{4}

Importance of Circulatory System and its Adjustment to Exercise and Training

The simplest animals have no circulatory system. They are aquatic and all their cells are in direct contact with the water in which the animals live. Food material is either taken directly into the cells from the surrounding water or is digested in the simple alimentary tube and are absorbed from

\textsuperscript{4}Ibid.
there into adjacent cells. Oxygen diffuses from the surrounding water into all the cells and carbon dioxide and other waste products diffuse out.\(^5\)

In higher animals millions of cells which make up the animal body are at some distance from the surface and a circulatory system is necessary to carry the products of digestion from the alimentary canal and oxygen from the lungs to the cells throughout the body. Waste products are carried by circulation to the excretory organs.\(^6\)

The circulatory system exists for the sake of its capillaries, through the walls of which the exchange of oxygen, carbon dioxide, acids and other materials take place between the blood and the tissues. The heart in large part supplies the necessary force to propel the blood; the arteries, by their elastic and muscular tissue, maintain an adequate pressure for the period between the heart beats and thus provide a


\(^6\)Ibid.
steady flow through the capillaries; and the veins conduct the blood away from the capillaries. 7

Regular intense physical activity or exercise has a number of physiological benefits. Physical exercise improves physical fitness. It improves the efficiency of circulatory system, indicated by the reduction of required coronary blood flow at rest and during exercise. It increases the work capacity and the efficiency of oxygen transport by the blood and oxygen utilisation by the tissues. It decreases the resistance in the blood vessels of the muscularure, thereby decreasing arterial blood pressure. The metabolic effect of exercise can result in improved glucose tolerance and thus less rise of blood fats and triglycerides following a meal. While it will not by itself lower the cholesterol, intense exercise does have a beneficial effect in preventing arteriosclerosis by its contribution to the removal of some cholesterol deposited in the arterial walls. It decreases the coagulity of the blood and thereby improves protective mechanism against blood clots. It quite possibly increases the number of communicating blood vessels in coronary circulation. Thus

7 Ibid.
it improves the chance of preventing a heart attack. Its psychological effect improves self respect, feeling of well being and tolerance of psychological stress.  

When analyzing the relevance of heart circulation to performance ability one must distinguish between regulatory changes and growth changes in cardiorespiratory adaptation. When an athlete begins training, the regulatory changes appear first, whereby an improved maximum oxygen intake is attained. The effect of this improved regulation is a decrease of the heart rate at rest, as well as a decrease of heart rate and of blood pressure during exercise. This is the result of a diminished adrenergic activity. It can already be seen at this training stage that a decrease in oxygen consumption of the myocardium occurs during exercise.  

A knowledge of cardiovascular adaptation in trained athletes is a requirement for understanding extreme athletic

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achievements. However, the cardiovascular system is only one of many factors which can theoretically limit the performance ability of endurance athletes. Next to cardiac output, the performance ability depends on the diffusion capacity of the lungs, the blood transport capacity and energy conversion in muscle. In addition, the amount of energy supplying substrates is also important.

Importance of Respiratory system and its Adjustments to Exercise and Training

The anaerobic processes, working without access to molecular oxygen, were developed several billion years ago. Evidently the atmosphere surrounding our planet was originally more or less oxygen-free. During some two billion years of time, the atmosphere became more and more like the 21% oxygen mixture we are breathing today. For the ancestry cells energy was necessarily yielded by anaerobic processes, by fermentation.10

The gradual increase in oxygen concentration of the atmosphere probably led to the extinction of many anaerobic

organisms, for oxygen was more or less toxic for key processes within their cells. Other organisms could adapt by developing aerobic energy-yielding processes. A milestone may be the birth of the first organisms with cells and nuclei. That milestone is presently placed 1.4 - 1.5 billion years ago. In the mitochondria the pyruvate could enter the citric acid cycle and respiratory chain. A glucose unit could yield about 18 times more energy for resynthesis of ATP than in the fermentation process. Of the prokaryotes we have a full spectrum of tolerance for oxygen from complete intolerance to fully aerobic prokaryotes. In our bodies the muscle cells are the only cells which still 'remember' the very old process to yield energy under anaerobic conditions to support the citric acid cycle when it becomes disabled due to lack of oxygen. The potential is limited, however, at least partly due to an accumulation of lactate.\textsuperscript{11}

The purpose of respiration is to provide oxygen metabolism to the body cells and to eliminate the carbondioxide resulting from oxydation. Therefore the respiratory mechanism is so adjusted that its function corresponds directly to the change of metabolism.

\textsuperscript{11}Ibid
Respiration essentially plays a two-fold part in the body during physical exertion. On the one hand, it supplies the oxygen required by the muscles; on the other-hand, it serves to keep the acid-base balance of the blood constant within certain narrow limits.\(^\text{12}\)

The volume of air breathed varies with every change in bodily activity; sleeping, sitting, walking, and running; the amount of air breathed can not be estimated from mere inspection. A considerable increase, 200 and sometimes even 300 percent, may not be noticed by the breather himself or by a casual observer. The total volume of the air inhaled and exhaled during a certain period rarely can be exactly controlled by will, but is automatically adjusted to maintain the interior atmosphere of the body nearly stable as possible.\(^\text{13}\)

Control of the cardiorespiratory system is a difficult job, even under resting conditions. Many respiratory and circulatory adjustments are necessary during exercise in order


\(^{13}\) Kapovich, and Sinning, Physiology of Muscular Activity, p. 85.
to meet the increased metabolic demands of the working muscles. Furthermore, to do this most efficiently, all of these adjustments must be controlled and coordinated with each other.

Basically, this difficult job is carried out by the central nervous system through the combined efforts of the respiratory and circulatory centres located in the brain. These centres constantly receive information concerning the adequacy of gas exchange and transport, either directly or from a variety of receptors located throughout the body. Then, using this information as a basis, they elicit, if necessary, regulatory changes in pulmonary ventilation and blood flow.

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 accessible, exposing the blood to oxygen over as much as 100 square meters of surface, instead of a fraction
there of.\textsuperscript{14}

The trained man breaths more economically than the untrained. For the same task, he needs less air because he can utilize a greater portion of its oxygen than can the untrained one. This difference becomes pronounced when heavy loads of work are carried out.\textsuperscript{15}

Participation in the physical exercise of daily activities, sport and physical labour results in an increased demand for pulmonary ventilation - the exchange of air between the lungs and the atmosphere. While the control of pulmonary ventilation has been the subject of scientific investigation for approximately 100 years, we are still far from achieving an understanding of the complex series of events which results in the determination of tidal volume and breathing frequency which occur during various types of exercises. Under a wide variety of exercise and training conditions, we can say as much about what the mediating factors are not, as we can say about what they are. We have indeed, gathered many parts of the puzzle but no definite picture has emerged as yet.

\textsuperscript{14}Ibid., p.161.

\textsuperscript{15}Ibid.
In general, for obtaining optimum fitness many training programmes have been evolved among which the latest is to make programmes according to the energy requirements for the activity. That is by using aerobic and anaerobic training principles. For formulating specific training programmes in relation to aerobic and anaerobic training principles it is essential to avail the specific effects of these training in relation to cardio-respiratory response patterns against different work grades for assessing the cardio-respiratory status of their students or trainees in relation to demand of a particular game or activity.

Therefore, understanding the adaptation of the circulatory and respiratory systems due to anaerobic and aerobic training is important to the physical educator and coach, perhaps more so today than ever before. So this study had been undertaken to determine the effect of graded exercise on circulatory and respiratory variables among untrained, anaerobically trained and aerobically trained individuals.
Statement of Problem

The purpose of the study was to determine the effect of graded exercise on certain circulatory and respiratory variables among untrained, anaerobically trained and aerobically trained individuals at rest and immediately after different grades of work.

Delimitations

1. The study was confined to the male students of Scindya Vidyalaya, Gwalior Fort.

2. The number of subjects was delimited to sixty with the age group between 15 to 17.

3. Out of the physiological variables associated with circulatory and respiratory responses, this study was restricted to the following variables:

Circulatory and Respiratory variables:

1. Heart Rate
2. Blood Pressure
3. Haemoglobin Concentration
4. Cardiac pulmonary Index
Adynamic stage

Dynamic stage

5. Tidal volume
6. Minute ventilation
7. Respiratory Rate
8. Maximum Oxygen consumption

Limitations

1. The present study involves only those subjects who were residing in the hostels of the school. The subjects had more or less similar type of food and followed the same type of programme. Even though the subjects were instructed to avoid all physical exertion other than the specific programme administered by the investigator, some of the factors like daily habits, life style and similar other individualized factors which might have had an influence on the results of the study, could not be controlled by the investigator.

2. The subjects were urged to put up their best performance in all variables, but no specific motivational technique was employed by the investigator.
3. Non availability of sophisticated equipment was considered as another limitation for the purpose of this study.

**Hypothesis**

On the basis of literature reviewed and from the scholar's own experience in Physical education, it was hypothesised that there would be a significant difference in circulatory and respiratory variables among untrained, aerobically trained and anaerobically trained individuals at rest as well as at different grades of exercise levels.

**Definitions and Explanations of Terms**

**Circulatory Response**

Whenever human body is subjected to any work of sub-maximal nature, certain circulatory adjustments occur to meet the increasing demands of oxygen. Such adjustments may be defined as circulatory responses to an exercise/work stimulus.

**Respiratory Response**

Whenever human body is subjected to any work of sub-maximal nature certain respiratory adjustments occur to meet
the increasing demands of oxygen. Such adjustments may be defined as respiratory responses to an exercise/work stimulus.

In this study the circulatory and respiratory responses refer to those circulatory and respiratory adjustments to different grades of exercise which take place in the body of the experimental groups as a result of administration of aerobic or anaerobic training programme.

**Graded Exercise**

Administration of standard loads of varying degrees.

In this study the graded exercise refers to the pedalling of bicycle ergometer at the grades of 60, 90, 120 and 150 watts at 60 revolutions per second for five minutes duration.

**Training**

Training is an exercise programme to develop an athlete for a particular event. Increasing skill of performance and energy capacities are of equal consideration.
Training consists of a methodical application of general and special exercises, performed either in groups or individually and designed to bring the athlete to his peak condition at the day of the competition.  

Aerobic Training

Brief bouts of repeated exercise (interval training) as well as continuous, long-duration work (continuous training) enhance aerobic capacity, provided the exercise is sufficiently intense to overload the aerobic system. Interval training, continuous training, and fartlek training are three common methods to improve aerobic fitness.  

Anaerobic Training

Anaerobic training is defined as training which enhance the ATP-CP energy capacity of specific muscles. The activities selected must engage the muscles at the appropriate speed of movement for which the athlete desires improved anaerobic power. Not only does this

16 Encyclopaedia of Sport Sciences and Medicine, "Cardiorespiratory Endurance", by Frances Z. Cumbee.

17 Frank Katch and L. Katch Exercise Physiology, p. 270.
enhance the anaerobic metabolic capacity of the specific trained muscle fibres, but it also facilitates the recruitment of the appropriate motor units used in actual movement.

The capacity to perform and persist in all-out exercise for brief periods of time up to 60 seconds is largely dependent on ATP generated by the immediate and short-term anaerobic energy systems.\textsuperscript{18}

Heart Rate

The distention of the arterial wall at the beginning of systolic ejection of blood is not confined to aorta but travels down the arteries as a wave followed by a wave of recoil. In the arteries that lie close to the body such as radial artery of the wrist, the arrival of the wave of distention and subsequent recoil may be felt as a distinct throb, the pulse, which affords a convenient method for counting the heart rate.\textsuperscript{19}

\textsuperscript{18}Ibid: P.278.

\textsuperscript{19}Morehouse and Miller, \textit{Physiology of Exercise}, P.82.
Blood Pressure

Blood pressure has been defined as the force or pressure which the blood exerts on the walls of the blood vessels in which it is obtained. When the left ventricle contracts and pushes the blood into the aorta, the pressure produced is known as the systolic blood pressure. When complete cardiac diastole occurs and the heart is resting with no ejection of blood, the pressure within the blood vessel is termed as the diastolic blood pressure.

Haemoglobin

Portion of the red blood cell containing iron and capable of combining with oxygen.

Cardio-Pulmonary Index (C-P Index)

C-P Index is the most readily performed test for the determination of cardio-respiratory endurance. It involves 7 parameters and will provide invaluable information concerning endurance of the heart and lungs. Cardio-respiratory endurance can be calculated by using the


21 Larry G. Sheaver, Essentials of Exercise Physiology (Delhi: Surjeet publications, 1972), P.298.
the following formula:

\[
C-P \ Index = \frac{VC + MBH + MEP + Age}{SP + DP + PR}
\]

where,

- VC is the vital capacity in 100 ml. units which is the maximum volume of air that can be forcefully exhaled from the lungs following a maximal inspiration.

- MBH is the maximum breath holding time in seconds. This can be defined as the maximum period of time of holding the breath followed by maximum voluntary inspiration.

- MEP is the maximum expiratory pressure in mm.Hg. For the purpose of this study this can be defined as the maximum pressure exerted by the expired air which can be held for three seconds after an inhalation.

- SP is systolic blood pressure in mm.Hg, and DP is diastolic blood pressure in mm.Hg.

- PR is the pulse rate per minute which is the wave of distention and recoil after systolic ejection of blood in the peripheral arteries (e.g., radial artery) expressed as beats per minute.

- Age is the actuarial age in years.
C-P Index Dynamic stage

This is one of the good tests for the determination of cardio-respiratory efficiency at resting stage. It can be found out by using the above formula in which all the variables have to be measured at resting stage.

C-P Index Dynamic stage

Dynamic stage of the cardio-pulmonary exercise tolerance test is performed directly after the subject has completed the 5000 foot-pounds of work. 22

Tidal Volume

Volume of air inspired or expired per breath. 23

Minute Ventilation

Minute ventilation may be defined as the volume of air breathed each minute. 24

22 Encyclopaedia of sports sciences and Medicine, P.275.

23 Fox and Mathews, The Physiological basis of Physical Education and Athletics, P.555.

24 Mcardle, I Katch and L.Katch, Exercise Physiology, P.162.
Respiratory Rate

The number of breath per minute is defined as the respiratory rate. 25

Maximal Oxygen Consumption

The maximal rate at which oxygen can be consumed per minute, the power or capacity of the aerobic or oxygen system. 26

Significance of the Study

1. The results of the study would reveal the specific effects of anaerobic or aerobic training in relation to cardiorespiratory response patterns against graded work loads.

2. The observations made in this study would help those concerned with coaching and training to formulate specific training programmes in relation to anaerobic and aerobic activities.

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25 Ibid.

26 Ibid; p. 550.
3. The findings of this study would in general assist the physical education teachers and coaches for assessment of cardiorespiratory status of their students or trainees in relation to demand of a particular game or activity.

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

*Note: Investigated the effect of regular periods of duration, using a substantial work load on the biologic.*

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*Arthur Henry Stian, "Cardiovascular Responses of selected athletic aged subjects to regular periods of exercise" Dissertation Abstracts International 1942 (March 1970), 795 A4*