CHAPTER II

REVIEW OF LITERATURE AND HYPOTHESES
CHAPTER II

REVIEW OF LITERATURE

The discussion in this chapter centres around four areas relating to the topic with various sub-divisions:

I. The Phenomenon of Cardio-Vascular Responses During Rest, Exercise, Recovery and Adaptation to Training.

II. Recuperative Procedures and Recovery.

III. Maximal Work output.

IV. Synthesis and Formulation of Hypotheses.

2.1 The Phenomenon of Cardiovascular Responses During Rest, Exercise, Recovery and Adaptation to Training

The function of the circulatory system is to provide a proper milieu for the functioning of the cells. There is continuous cell activity and proper cellular environments can only be maintained through continuous flow of blood to the tissues. The demand of blood flow is closely related to the state of tissue metabolism, which is different in resting conditions and vigorous exercises. A change in the rate of metabolism usually requires adjustments in the whole cardiovascular system.

The cardiovascular responses during rest and physical activities can be investigated through microcirculation, the heart rate, cardiac output, stroke volume, blood pressures
and regional blood flow (Anderson 1968). In the present investigation, the cardiovascular responses during rest, exercise, recovery and adaptations to training are based upon recording of heart rate, blood pressures and pulse pressure.

Heart rate is an indicator of the intensity of physiological effort and one of the measures of cardiac output. Blood pressure levels indicate pumping action of the heart. The systolic pressure is a measure of the capacity of the heart to generate enough force to overcome peripheral resistance and to propel the blood in the arteries. It is an index of energy expended by the heart. The diastolic pressure is a measure of the elasticity and peripheral resistance of the blood vessels and an index of vasomotor tone. The pulse pressure (the arithmetic difference between systolic and diastolic pressures) is caused by the ejection of blood into aorta during systole. It indicates the condition of the muscular wall of the heart and a rough indicator of the effective pumping force of the heart or stroke volume.

2.1.1 Cardiovascular Responses during Rest:

Heart rate and blood pressure are influenced by many factors such as age, sex, body size, body position (postures), time of recording, smoking, alcoholic intake, ingestion of food, emotions, body and environmental temperatures, physical condition of the individual.
Most observations have shown that the pulse rate is definitely affected by body position. The rate is lowest in lying and highest in standing. Digestion of food accelerates the heart rate for two or three hours. A high environmental temperature may greatly increase the frequency of heart beat. Variations in the emotional state effect the pulse rate much more than postural changes. Among anemic subjects the pulse rate will be higher. It is, therefore, difficult to find out the exact and true resting values (Best and Taylor-1967; deVries-1970; Karpovich and Sinning-1971). The exercise physiologists have thus mentioned different normal ranges among adults:

Heart Rate:

H.A. deVries (1970) = 40-100 per min.
Karpovich & Sinning (1971) = 38-110 " "
The American Heart Association = 50-100
Morehouse & Gross (1977)
- Boys = 80-84
- Girls = 82-90
- Men = 72-76
- Women = 82-89

Pressures

<table>
<thead>
<tr>
<th>Systolic (mm/Hg)</th>
<th>Diastolic (mm/Hg)</th>
<th>Pulse Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reidman (1950)</td>
<td>110-140</td>
<td>65-90</td>
</tr>
<tr>
<td>Best &amp; Taylor(1967)</td>
<td>90-120</td>
<td>60-80</td>
</tr>
<tr>
<td>Anderson (1968)</td>
<td>120-140</td>
<td>70-90</td>
</tr>
<tr>
<td>Karpovich &amp; Sinning (1971)</td>
<td>110-135</td>
<td>60-90</td>
</tr>
</tbody>
</table>
Karpovich and Sinning (1971) reviewed the literature on arterial blood pressure and found no general agreement about the relative values in the recumbent and erect postures of the body. A healthy person in the standing position might have a blood pressure either higher, lower or the same as in recumbancy. But emotional excitement could cause a rise in blood pressure.

The physiologists (Reidman-1950, Best and Taylor-1967, deVries-1970, Karpovich & Sinning-1971) have thus admonished to control the factor which influence the heart rate and blood pressure in resting condition. Some investigators have opined that pulse rate after a standard exercise could be more reliable than the pre-exercise resting pulse rate, which might be affected temporarily by various complicating influences (Karpovich and Sinnings - 1971).

2.1.2 Cardiovascular Responses During Exercise

Variability in the cardiovascular response to exercise is associated with the variety of factors including age, sex, conditioning and training, duration of exercise, obesity, diet, drugs, environment etc. The effect of these and many other factors have been incompletely studied (Buskirk, 1974).

Of all physiological conditions, exercise has the most powerful effect upon the heart rate and arterial blood pressure. Anderson (1968) has pointed out that during
light exercise, there would be first exaggerated increase in heart rate and a subsequent decline to a lower level and maintained throughout the period of exertion. However, during prolonged work with heavy load; there would be a tendency for the heart rate to increase in order to achieve adequate cardiac output. deVries (1970) has opined that rise in heart rate would be proportional to the work load per unit of time or intensity.

Karpovich and Sinning (1971) found out that during exercise the change in heart rate would depend upon the individual. For equal intensity of work the heart rate differed from individual to individual. At the beginning of exercise the heart rate would rise rapidly and than plateau. In intensive exercise, there might be a secondary rise.

The highest attainable heart rate due to strenuous exercise has been investigated by several exercise physiologists.

Astrand (1958) indicated the following average maximum heart rate: 15 years, 210; 25 years, 200; 35 years, 190; 40 years, 180; 45 years, 170; 50 years, 160; and 55 years, 150. According to Anderson (1968) the highest attainable heart rate (age of 20 years) could be about 200 beats per minute, which would reduce to 155 at the age of 70 years.

Faria and Philips (1970) studied the cardiac responses of young boys and girls during twenty minutes of Gymnastics
and mentioned the following cardiac rate:

<table>
<thead>
<tr>
<th>Activity</th>
<th>Boys Range</th>
<th>Mean±SD</th>
<th>Girls Range</th>
<th>Mean±SD</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vaulting</td>
<td>126-170</td>
<td>140.3±14.4</td>
<td>132-195</td>
<td>153.4±19.8</td>
<td>1.3150</td>
</tr>
<tr>
<td>Tumbling</td>
<td>135-175</td>
<td>149.4±12.1</td>
<td>135-185</td>
<td>152.7±15.2</td>
<td>0.8409</td>
</tr>
<tr>
<td>Floor Exercise</td>
<td>140-170</td>
<td>156.0±10.9</td>
<td>132-180</td>
<td>158.0±16.7</td>
<td>0.2243</td>
</tr>
<tr>
<td>Trampoline</td>
<td>156-190</td>
<td>179.9±9.5</td>
<td>144-192</td>
<td>175.1±12.7</td>
<td>0.1743</td>
</tr>
</tbody>
</table>

There was no significant difference between the boys and girls heart rate response to trampoline, floor exercise and vaulting activities.

The circulated responses on the three pressures (systolic, diastolic and pulse pressure) during exercise has been investigated by several exercise physiologists.

According to Reidman (1950) in very moderate exercise (slow walking), there would be slight rise in systolic but no difference in diastolic, whereas in vigorous exercise the systolic pressure would rise and decline after exercise to resting level within about the same time it took to rise.

Best and Taylor (1967) have opined that the systolic pressure during the muscular effort or even immediately before it, would commence to rise and may reach a height of 180 or 200 mm Hg. except in well trained persons or athletes. This could invariably be associated with a large
increase in heart rate to 150-180 per minute. In a light exercise the diastolic pressure might remain at normal level while the systolic and pulse pressure would rise.

Anderson (1968) has pointed out that systolic pressure increases during exercise. The initial period of increasing systolic pressure during performance of rhythmic exercise, lasting for one to two minutes, after which a fairly constant value is reached and maintained, the level of which depends upon the intensity of exercise. The diastolic pressure remains practically unchanged by light and moderately heavy exercise, but may increase slightly during heavy exercise. As a consequence of the differential rise in systolic and diastolic pressures, the pulse pressure increases greatly.

deVries (1970) has opined that blood pressure would be affected by the type of exercise and intensity of exercise and physical condition of the subject. In rhythmic activities (cycling), the systolic would rise on the average of 8 mm Hg. for each increase in work load of 2,000 foot-pounds per minute. In Isometric exercise with glottis closed there would be a sharp rise in both the pressures. The diastolic pressure follows the course of systolic, but to a lesser degree.

According to Karpovich and Sinning (1971), the systolic pressure showed increase in both athletes and non athletes; but diastolic changed slightly because of less peripheral resistance and elasticity of the walls of artioles. The
non-athletes did not show as large an increase for a given heart rate. The pulse pressure tended to increase and decrease with the systolic pressure.

2.1.3 Cardio-Vascular Responses During Recovery:

There seems to be an agreement that the pulse rate curve during the period of recovery after exercise is the most useful single measure of circulatory fitness.

According to Clarke (1975) recovery process after exercise consisted of two components: one operating during the very early time period, the other controlling events later. There would be a spontaneous nature of the recovery following exercise during the early seconds, and by three minutes a steady state be achieved with no further gains.

Campbell (1969) analysed the trend on the heart rate deceleration following graded intensity of exercise on boys. His data suggested a rectilinear relationship between intensity of exercise and recovery. deVries (1970), Karpovich and Sinning (1971) have pointed out that heart rate for the first two and three minutes after exercise decreased almost as rapidly as it increased. After this initial rapid decrease further decline in heart rate occurred more slowly at a rate that was roughly related to the intensity and duration of the work. The heart rate might fall below the pre-exercise level, therefore, post exercise
rate could be more reliable than pre-exercise heart rate. Among healthy individuals the recovery rate was faster.

Adolph (1974) has emphasised that recovery is faster when departure from resting is greater. This fact represents a useful property of a recovery. It should, however, be pointed out that the pulse frequency is modified by mechanical, thermal, chemical and nervous influences. Thus recovery of heart rate towards its resting value takes time. Fast recovery is advantageous to the individual, who has it.

There is a common belief that in a group of subjects after a standard exercises, pulse rate would be higher in those individuals whose resting rates were also higher. Knehr (1942) and Taylor (1944) observed no relationship between basal pulse rate and post exercise pulse rate.

Tuttle and Salit (1945) experimenting on young men and women who exercised on a bicycle ergometer, came to the conclusion that the relationship between resting and post exercise pulse rate depends on the strenuousness of the exercise. The findings were substantiated by Campbell (1969) and Karpovich and Sinning (1971).

The kinetics of recovery from exercise is affected by training and the process take place at a quicker rate in the trained persons. Numerous investigations of heart rate and arterial blood pressure recovery from standard exercise have revealed faster recovery among the trained

Shapero, Shoenfield and Shapero (1976) investigated the recovery heart rate after sub-maximal work. The result of the study showed that the recovery heart rate at the very beginning of the recovery period was mostly influenced by the heart rate at work at the \( V_{o2} \) maximum. The difference between work and resting heart rates had a less significant influence on this recovery period. It was opined that the higher stroke volume during the recovery period could be one of the factors to influence the recovery heart rates.

Estimation of the speed of heart rate deceleration during recovery after exercise is considered to be an important criterion, visualising regulatory response. Montoye (1953) used "Recovery Index" to find out its relationship with blood lactate, after submaximal cardiovascular test of 5 minutes duration.

The equation for R.I. was:

\[
R.I. = \frac{\text{duration of Ex. (in sec.)} \times 100}{2 \times \text{sum of pulse counts in recovery}}
\]

The recovery index reflected positive correlation with blood lactate.

Ardisson et al (1973) investigated the cardio-respiratory effect of interval-training and used the following equation for recovery index:
R.I. = \frac{\text{Max. H.R. (B/min)} - \text{R. H.R. (B/min)}}{\text{Rec. Time (sec)}}

The results showed a faster heart rate recovery speed after training - a sure criterion of training.

Shaprio, Shoenfield and Shaprio (1976) investigated recovery heart rate after submaximal work with the help of "Mean Decrease Index:

\[
\text{M.D.I.} = \frac{\text{Ex H.R.} - \text{Rec HR}}{\text{Ex HR}}
\]

In the present study "per cent Mean Decrease Recovery Index" has been used based upon Shaprio et al. equation (1976).

\[
\text{MDRI (\%)} = \frac{\text{Ex HR} - \text{Rec HR} \times 100}{\text{Ex HR}}
\]

The blood pressure after exercise and during recovery might be established after ten minutes. In speed exercises the return to normal would be slow (Reidman, 1950). Best and Taylor (1967) found return of blood pressure to resting level from 1 to 4 1/2 minutes after light exercise. According to Anderson (1968), blood pressure drop immediately to sub resting values, the minimum is reached 5 to 10 seconds after cessation of work. Subsequently, the pressure rises to a little above the pre-exercise level. He has further emphasised the importance of nervous regulartory mechanism affecting the behaviour of circulation during recovery systolic.
Karpovich and Sinning (1971) have opined that post exercise (recovery) blood pressure depends upon two factors: individual differences (fitness) and the time of measurement after exercise. The drop in pressure after exercise is very rapid and diastolic is always subnormal because there is a loss of resistance due to lack of muscular contraction and the blood flows freely into the capillaries. Pulse pressure follows the course of systolic blood pressure.

2.1.4 Training Programmes and Cardiovascular Adaptation:

The physiological effects of exercise and training depend on the specificity of training. McCafferty and Horvath (1977) reviewed the literature on specificity of exercise and specificity of training concluded on the basis of bulk of evidence that training affects would depend upon specific types of exercises, intensity and duration of training programmes. The recovery process played an important role in optimal training routines.

Merrit, Squires and Rodahl (1962) found that a rope-skipping programme produced significant gains in predictive maximum intake and in the pulse responses to the submaximal bicycle ergometer work. Curtis (1963) found that a rope skipping programme for elementary school children resulted in no significant changes in
endurance, leg power, agility or coordination. Cassino (1964) indicated that a programme of rope skipping would improve the cardio-vascular fitness of adult males. Garrett, Sabic, Pangle (1965) showed a research evidence that running on the spot, skipping, bench stepping during volleyball instructions would enhance cardio-vascular fitness. Baker (1968) conducted a study on 92 volunteers and randomly placed into two groups: I - Rope-skipping (N=46) and II - Jogging group (N=46).

<table>
<thead>
<tr>
<th>Skipping Type</th>
<th>Turns per minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slow</td>
<td>125-130</td>
</tr>
<tr>
<td>Medium</td>
<td>135-145</td>
</tr>
<tr>
<td>Fast</td>
<td>150-160</td>
</tr>
<tr>
<td>Speed</td>
<td>165-170</td>
</tr>
</tbody>
</table>

Jogging programme consisted of 30 minutes per day, five days a week for six weeks. Harvard step test was used to measure cardio-vascular efficiency. The means of pre and post heart rates per minute were: 206 and 185, for the skipping group and 207 and 184 for the jogging group. The results of the analysis of data would seem to warrant that both rope skipping and jogging improve cardiovascular efficiency significantly at .05 level.

Smith and Stransky (1975) investigated the cardiovascular adaptation due to cycle ergometer training on young women. Sixteenth healthy, young women (10 experimental and 6 control) participated on a seven weeks training programme consisting of 16 minutes/day.
Three days/week session of continuous riding on a cycle ergometer. The mean heart rate and pulmonary ventilation of the experimental group decreased significantly and substantial gains in cardiovascular efficiency during both submaximal and maximal work.

It was further concluded that stationary bicycle riding is an effective alternative to other rhythmic exercises in developing cardiovascular efficiency.

Studies on blood pressure have shown conflicting results.

Knehr Dill and Heufield (1942), Brouha (1960), Taylor (1971), Montoye Metzner Keiler (1972) have revealed lower resting systolic and diastolic pressures after training.

Pollick et al (1969), Karpovich and Sinning (1971), Penny and Wells (1975) found no significant changes in trained and untrained.

deVries (1970) has opined that, there is considerable evidence (not yet conclusive) that if blood pressure is above normal values, endurance type physical training can result in decreasing both systolic and diastolic values toward the normal.

Probably, the cardiovascular adaptation to training depends upon the type and intensity of exercise and age of subjects.
The Threshold for a Training Load:

Athletic trainers are utilizing both continuous running and intermittent or interval training for cardiovascular efficiency. Karvonen (1959) has found out that training with 60% maximum HR between the resting and the maximum rate - approximately 148 beats per minute would be the required training stimulus. Budgetchell (1976) have advocated 75% of the HR maximum - approximately 150-170 beats per minutes.

The intensity factor in training is gaining ground (Rosentwieg and Burrhus, 1975). The present investigator has followed Budgetchell equation:

\[
\text{THR(75\% HR max)} = \left( \frac{\text{Maximum HR - Resting HR}}{0.75} \right) + \text{Rest HR}
\]

as a training load for the short exercise bouts.

The exercise consisted of running on the spot, jumping jacks, jump squats and fast cycling, interspaced with the practice of a particular recovery technique. The training programme was formulated to enable the subjects to practice particular recovery technique immediately after exercise. Recovery technique cannot be practiced without exercise bouts.

Rationale of Cardiovascular Adaptation to Training

In general, as training progresses, the heart rate for any given workload would decrease. The physically fit person would show slow heart rate for any given exercise.
work load. The trained individual would also produce a greater work load (deVries-1970, Karpovich and Sinning-1971; Clark-1975, Bud Getchel-1976).

Raab (1960, 1961, 1964, 1969), a long time leader in prevention of heart diseases, had emphasised the autonomic control of the heart. The rate and metabolism of the heart could be established due to a balance between the parasympathetic system (Vagus nerve) and the sympathetic system (Accelerator nerve). This balance would be established in the midbrain and mediated through release of neurohormonal transmitters. Exercise and training would bring about Vagal preponderance, as indicated by the slower heart rate in the athletes both at rest and under any given workload. He further opined that neurohumeral imbalance (sympathetic preponderance) could be caused jointly by (1) Hypothalamic-Stimulating emotional Socioeconomic pressures, and (2) a deficiency of vagal and sympathoinhibitory counter regulation resulting from lack of exercise. Massicotte and Corriveau (1979) substantiated the views of Raab by stating that training would modify the equilibrium between sympathetic and predominant influence of the parasympathetic activity.

Anderson (1968) has observed sports bradcardia (diminished heart rate) due to training. In well-trained athletes the values around 40 beats per minute were
observed under true basal conditions. The pumping capacity of the heart was manifested due to increase in stroke volume and a corresponding reduction of the heart rate. Athletes showed lower "maximal" heart rate in several types of exercises than non-athletes.

In his opinion, the reduced maximal heart rate due to training could be related to an increased pumping capacity. Because of this, during maximal exercising involving the larger part of the muscle mass, there would be no need for maximal activation of the cardiac pump. The effect of training upon the functioning of the heart was established quickly - within 2 weeks.

The training bradycardia might well be associated by a "habituation" process involving brain structures — the brain stem — which controls and regulates cardiac performance.

Fardy (1971) investigated the influence of physical activity on selected cardiac cycle time components. The study indicated that electro-mechanical lag (Q-1st heart sound (EML), from the QRS onset of the electrocardiogram to the beginning of the first heart sound) and heart rate decreased significantly with the increase of physical activity. In addition, it was observed that increased physical activity resulted in significant lengthening of intervals denoting ventricular systole. Longer contraction...
and lowered heart rate indicate increased stroke volume, more characteristic of the conditioned heart.

Badeer (1975) has propounded the thesis that the hypertrophy of the heart, as a consequence of athletic training, is more importantly related to the development of bradycardia and cardiac dilatation. These changes seem to provide a greater maximum cardiac output.

Training brings about a complex of changes in cardiovascular responses during rest, exercise and recovery, all of which together interact to bring about a more effective adjustment of the organism according to the demands.

2.2 Recuperative Procedure and Recovery

Athletic trainers, exercise physiologists have advocated various types of recuperative procedures. Perusal of related literature have revealed the following recovery techniques:

(i) Active Recovery, consisting of walking, jogging or cycling with a lesser load (cycle ergometer).

(ii) Passive Recovery, consisting of lying or sitting passively.

(iii) Recovery postures such as sitting, lying with arms and legs in elevated position.

(iv) Relaxation techniques such as savasana (yoga), Progressive Relaxation, Autogenic and other techniques.
2.2.1 Active and Passive Recovery and Recovery Postures:

At the present time most superior middle distance runners recover during interval training by jogging. It is unknown whether jogging or walking is preferable or desirable. Fred Wilt (1968) has opined that one minute of walking usually results in as much or more recovery as two minutes of jogging on the basis of decrease in heart rate. Jogging requires more energy and fatiguing than walking.

deVries (1970) has advised a few minutes jogging as a cooling out procedure after heavy exercise. He opined that jogging should be encouraged to avoid blood pooling in the extremities, otherwise it could result in shock or muscle cramps.

Reactive inhibition is another hypothesis put forth by Belzer and Peters (1972) and are in favour of active recovery. The experiment was designed to shed light on the question of whether or not gross bodily activity can affect the rate of recovery from reactive inhibition developed while performing relatively sedentary work.

Reactive inhibition is caused by the accumulation of a substance which inhibits an organism's reaction to a repeated stimulus, and according to Hull (1965) this substance could be removed progressively by the blood stream to produce "spontaneous recovery".
It was concluded from the study that young male volunteer subjects (N=32) age 19-23 years recover more rapidly from reactive inhibition developed during five minutes of continuous rotary pursuit work if they do 30 side-straddle hops during a 2-minutes rest pause than if they remain sitting in a chair. Gross motor activity could have possibly increased blood flow to the site of inhibition.

Bud Getchell (1976) has also favoured tapering off after completion of the main workout which is best accomplished by a continuation of activity at a lowered intensity, such as walking or intermittent jogging. Physiologically, tapering off would help the muscles to assist in pumping the blood from the extremities back to the heart and thus prevent pooling of the blood.

Tapering-off, or cooling out after prolonged physical exertion has been accepted by most coaches on empirical grounds as active recovery. Molner (1976) has investigated this active recovery procedure experimentally with the help of electrocardiogram. He investigated on 13 male healthy college volunteers who cycled the ergometer with 900 k.p.m./min. at 50 rpm to exhaustion. Passive and Active recovery procedures were used. Passive recovery consisted of 10 minutes of sitting on cycle without moving the legs and arms and active recovery, riding the ergometer with 300 k.p.m./min at 50 rpm.
Results showed that active recovery yielded longer duration for Left Ventricle Ejection Time and Cardiac Time during early phases of recuperation (0-4 minutes of recuperation). The longer duration would indicate an advantage of Active Recovery over Passive Recovery immediately at the Cessation of the work period. It would thus support the practice of tapering off after a bout of hard physical work.

Weltman et al. (1978) investigated the effects of active and passive recoveries after high intensity, short duration exercise on lactate removal and subsequent performance on bicycle ergometer. Results reveal significant improvement in lactate removal and higher subsequent performance in favour of active than passive recovery.

The faster lactate removal during active recovery can be due to greater oxidation of lactate in slow twitch muscle fibres. Therefore, recruitment of these fibres during recovery would greatly increase the disappearance of lactate in comparison with passive recovery, during which slow twitch muscle fibres are less involved (Jorfeldt-1970).

Gritin et al. (1976) have further purported the efficacy of active recovery (light exercise) prior to heavy exercise. It was found out that the adjustments in oxygen uptake demanded by heavy exercise were faster
when the heavy exercise was preceded by light exercise rather than rest. Cardio-respiratory adjustments through light exercise prior to the event would reduce the initial time lag and oxygen deficit, and might improve the performance which exhausted the anaerobic capacity.

**Passive Recovery:**

Henry & Demoor (1951) indicated superiority of passive recovery to enhance the rate of heart rate recovery and return of $\text{Vo}_2$ uptake to baseline levels. Royce (1969) found that after cessation maximal work the largest decrease of $\text{O}_2$ consumption and heart rate occurred during the first minute of recovery, and the decrease was greater in passive than in active recovery.

**Postures & Recovery:**

Parker (1967) compared two methods of recovery on subsequent work performances. Twenty college women were selected who had a minimal submaximal run on treadmill, a 12 minute recovery period and then ran to exhaustion on the treadmill. Half of the group recovered supine with the legs elevated and the other half walked for eight minutes; reclined for two minutes, while measurements were taken and then walked for two minutes before the run to exhaustion.

The methods of recovery had no significant effect on the all out run times nor on the return of heart rate, respiratory rate or systolic blood pressure.
Harrison (1960) compared the effectiveness of four techniques that were useful in promoting recovery during a ten minutes rest period between experimental work period. The four techniques were (a) Lying Supine, (b) Elevation of the arms and legs, (c) Slow movements, (d) Watching movies.

Two swimming subjects and two treadmill subjects each completed 32 double work periods. Out of the four techniques, elevation of the arms and legs proved to be the most significant recovery techniques.

Chambers (1968) experimented on four University Ice Hockey players who did a series of timed skates at speed and followed by a four minute recovery period in one of the four different positions. The different postures were: normal sitting, normal sitting with massage on the legs, elevation of the legs and controlled breathing.

The effectiveness of the heart rate was in the following order: elevation of legs, Controlled breathing, Massage and normal sitting.

Murray and Robert (1969) tested eight subjects on swimming ergometer to investigate the effects of body positions and immersion on the recovery after swimming exercise. At the end of a five minute exercise period subjects were instructed to assume one of the four conditions.
subjects swam 200 yards for time after a rest period of three minutes. No significant differences were found when comparing the heart rates of the four recovery conditions and times for the 200 yards swim.

Kaufmann and Ware (1977) studied the effect of warm up and recovery techniques on repeated running endurance.

The subjects were 15 male varsity high school runners who ran a total of nine 300 yards dashes consisting of three trials of each treatment with a 20 minutes rest period between trials on three different testing days. The same pattern was repeated after 2 months. A randomised block factorial design (2 x 3 x 3) was used. Treatment: No warm-up and rest in sitting position. Standard warm-up and rest in legs elevated position.

The warm up with recovery techniques (legs elevated) demonstrated significant superiority of performance over the warm-up. The cause might be attributed to acceleration of venous return.

The bulk of the research literature have lent support to the active recovery as the best possible method for recuperation. Studies have indicated that since intense exercise results in the production of lactate (Astrand,
Hedman and Saltin, 1963; Hermansen, 1971; Hermensen & Osnes, 1972) which inhibits the rate of glycolysis (Karlsson Nordes, Jorefeldt and Saltin, 1970), as well as the mobilization of free fatty acids (Issekutz and Miller-1962). The removal of lactate after high intensity exercise might be critical for subsequent performance. Several studies have indicated enhancement of lactate removal during recovery by moderate aerobic exercise (Gisolfi, Robinson and Tussell-1966; Hermensen, and Stansvold-1972; Belcastro and Bonen-1975; Bonen and Belcastro-1976; Weltman et al-1978).

Weltman et al (1978) have hypothesized that oxidation of lactate in the muscles is the preferred metabolic pathway for its "disappearance", during light exercise rather than gluconeogenesis in the liver. In active recovery, lactate is utilized by the muscles for ATP production, through high-oxidative slow twitch fibers.

It has been postulated that with passive recovery (sitting or lying) the venous return to the heart is diminished. It might be attributed to the reduced pumping action of the leg muscles during the passive recovery and reduced ventricle filling (Molner-1976).

The 'compression' of the venous vascular bed (muscular pump) during active recovery through slow cycling, played an important role in facilitating venous return to the heart and the prevention of the large amount of pooling
in the lower limbs (Miyamura, Kitamura, Yamada and Mastui - 1978).

Recently Katch and Associates (1978) have investigated the relative merits of active (zero-load cycling, 50 rpm) vs. passive recovery (Quiet sitting) on 14 male subjects. The result showed that neither recovery condition in the experiment resulted in faster or more complete recovery in terms of net $\text{VO}_2$ uptake and heart rate. It was proposed that "fitness" level should be considered as the most important factor. Secondly, if lactic acid production and removal is considered, than the active recovery condition appears to be one of the best choice. The optimum level of recovery in terms of metabolic load will depend on the state of training of individual. A more fit individual, who has a higher anaerobic threshold (i.e. produces less lactate at any given time in comparison with an unfit person) would be able to recover actively at a higher metabolic load before signalling the onset of anaerobiosis. It would thus appear that knowledge of an individual's anaerobic threshold would be crucial in determining the level at which that individual should recover actively.

2.2.2 Relaxation Techniques and Recovery with Special Reference to Yogic Procedures

Relaxation is a neuro-muscular accomplishment that results in a reduction of tension in the skeletal musculature. Thus relaxation means "zero activity" of the voluntary motor apparatus (Steinhaus - 1965).
Relaxation or "letting go" is a technique, achieved through training. True relaxation is achieved not only through relaxing the muscles but also through mental calm (Kohler-1974). It is the integrated response through control of autonomic nervous systems and the endocrine system (Malmo-1959; Muracoski-1966; Sternback-1966).

There are many relaxation techniques, currently in vogue: Savasana yogic technique, Progressive Relaxation of Jacobson; Autogenic training of Schultz; Psycho-tonic training of dewinter; Bio-feedback training of Green and Green; Transcendental Meditation of Mahesh Yogi(TM). Some of the techniques are being used by the athletic trainers as a recovery procedure and as a psychosomatic preparation of athletes.

The main effect of relaxation techniques is to gain control of autonomic or involuntary nervous system (Psycho-Physiological), and the organs which are governed by it (Schultz 1956; Rele-1958; Kuvalayananda and Vinekar-1963; Fink,1963; Jacobson-1964; Steinhaus-1965; Datey et al. -1969; Romanowski et al - 1969 and 1971; dewinter -1970; Green and Green -1970; Hewit-1977; Remsberg,1979).

Yogic Relaxation Procedures:

The ability to achieve voluntary control over the autonomic nervous system has long been claimed by practitioners of yoga (Rele-1927 and 1958).
Savasana (dead pose), yogic technique is considered to be the oldest technique of relaxation (Rathbone-1969; Hewit-1977). It has established itself scientifically as a physical and mental relaxant (Chhina and Baldev Singh - 1975).

There is objective evidence that practice of savasana could reduce blood pressure and metabolic rate; slows down respiratory and heart rates and increases the skin temperature (Chhina 1965; Datey et al - 1969).

Perusal of literature shows that yogic relaxation procedures consisting of Pranayama and Asanas are based upon the following psycho-physiological principles: (i) Pranayama (breath control) technique influence the cardiovascular reflexes indirectly. The cortical electrical activity is influenced by the changes in the blood O₂ and CO₂ through the Recticular system. The main function of Pranayama seems to be to stabilise the emotional aspect of psychic apparatus (Kuvalayananda-1950; Vineker -1967; Mehta-1978; Sri Ananda-1980).

Slow diaphragmatic breathing in savasana reduces the blood pressure through reduction of the frequency and intensity of the proprioceptive and enterceptive. It is, therefore, postulated that Pranayama, probably influences the Hypothalamus through the continuous feedback of slow, rhythmic proprioceptive and enterceptive impulses and tend to set it at a lower level, thereby reducing the blood pressure (Datey et al., 1969).
(ii) The yogic asanas (Postures) are performed in a relaxed manner. The motor division (muscles) is set free or relaxed; and the autonomic and extra-pyramidal divisions are set in their natural rhythm (Vineker, 1967). The maximum benefits are derived through asanas, when they are performed in a relaxed manner, because in this position all the parts of the body are able to receive sufficient blood supply (Sri Ananda-1980).

Physiologically, when asanas are performed, the slow and static stretching of the muscles, tendons and joints (Proprioceptors) invokes the inverse myotatic reflex which help to relax the stretched muscles (Walker-1961; deVries-1970; Rao-1980).

(iii) Body Image: The concept of body image helps to induce relaxation. By 'Body Image' it means to have a clear mental picture of the body part to be relaxed (Kohler, 1974). In Savasana, during initial stages the attention is directed (mentally) to the body part to be relaxed during inhalation, which is relaxed during exhalation, which is relaxed during exhalation. Later on the attention should be diverted to the nostrils.

(iv) Control of thoughts is another principle which has been emphasised in yogic relaxation (Maxwell, 1968). Activation occurs not only as a result of external stimulation; but also due to exciting thoughts (Central
Phenomena). The ideo-motor reaction signifies that every mental image is accompanied by a slight motor action in the muscles (Kuvalayananda and Vineker-1963; Jacobson-1964; Edwin-1965; Sternback-1966). The mind should, therefore, be free from exciting thoughts and it should be replaced by mental image of relaxation and calmness. Conscious effort to relax should be avoided as it results in increased tension (Mehta, 1978). Relaxation can be achieved through effortless attitude (Mahesh Yogi-1963; Hewit-1977). Kuvalayananda & Vineker (1963), Datey et al (1969) have thus emphasised that in savasana the attention should be diverted from the body or any external environments to the nostrils. This transfer of attention will help to attain deeper relaxation.

Research Studies:

Datey et al (1969) studied the effects of "savasana" on the management of hypertension of various etiologies. A significant response was obtained in about 52% of the patients with arterio-sclerotic hypertension. The average mean blood pressure of 134 mm Hg. was reduced to 107 mm Hg - a reduction of 27 mm Hg, which was significant at .05 level. Savasana was performed for 30 minutes for three weeks.

Romanowski - 1969,1971; Pusek and Romanowski-1971, experimented extensively on yogic procedures and concluded:

Yoga exercises influence the parasympathetic system and improve vagaltone and more effective metabolic
balance. Under the influence of systematic yoga exercises, a better neurovegetative equilibrium and control of emotional reaction is established. The subjects had shown an ability to relax, which reduce tiredness after normal sporting exercises.

Dhanaraj (1973, 1974) conducted a study to determine the physiological influence of yoga in comparison with the effects of 5B x plan for physical fitness. He found out that both the systems are effective to reduce heart rate and respiration rate in basal state. But savasana proved to be more effective method for pulse recovery after exercise than 5BX plan (dynamic exercises).

Mall, Chaudhry and Giri (1978) investigated the effect of Relaxo-Concentration Yogic Training on two psychomotor tasks after submaximal exercise. Fifty healthy boys (10-14 years) were divided randomly & equally into two groups, experimental and control.

Following pre and post training psycho-physiological tests were given:

Pulse Rate: (i) Before exercise (ii) one minute after exercise (iii) Two minutes after exercise (iv) three minutes after exercise (v) Ten minutes after exercise and (vi) 20 minutes after exercise.

Respiratory Rate: It was tested at four stages: Before exercise, after exercise, ten minutes after exercise and 20 minutes after exercise.
Steadiness Test: Before exercise, after exercise, ten minutes after exercise and 20 minutes after exercise.

Tapping Speed: Before exercise, after exercise, ten minutes after exercise and 20 minutes after exercise.

The submaximal exercise consisted of stepping up and down a 18" bench for five minutes.

The experimental group was given yogic relaxo-concentration training (simple pranayama, selected Asanas, Savasana, Nasal and Forehead Gaze) for ten weeks: four times a week.

Following conclusions were warranted:

1. Yogic Relaxo - concentration training for ten weeks proved to be an effective method to hasten the process of recovery after submaximal stepping up exercise.

2. The experimental group after training showed significant improvement in Resting Pulse and Respiratory Rates.

3. Steadiness and tapping speed of the experimental group improved significantly.

Udupa (1978) conducted some research studies on physiological effects of yoga asanas. The investigation revealed reduction in blood pressure and pulse rate; reduction in the plasma catecholamines, and in the non adrenaline content due to practice of shirsasana, Sarvangasana and savasana.
Kocher (1979) conducted a study on 17 subjects to find out the effects of savasana on the extent of knee jerk. Results showed that training of savasana significantly diminished the knee jerk - a sign of relaxation.

Yogic relaxation procedures particularly savasana and Pranayama have shown potentials of cardiovascular recuperation. Savasana can prove to be effective recovery technique. So far its use in athletic training as recuperative technique has not been tapped and utilized.

Progressive Relaxation technique of Jacobson:

Scientific study of methodology for clinical application awaited the development of apparatus and methods for objective measurements and evaluation of the degree to which an individual would achieve voluntary relaxation. Jacobson and Carlson in 1920 developed a technique for evaluation of resting neuromuscular activity by using the amplitude of the knee jerk. In 1940 Jacobson improved his apparatus and called it neurovoltmeter. He later on suggested the use of surface electrodes to record action potentials from the muscles. This technique is currently known as electromyography and was perfected by deVries (1972).

Jacobson hypothesized from his clinical observations that the relaxation of the skeletal musculature can reduce the state of excitability of the sympathetic division of hypothalamus and finally of the cerebral cortex through
hypothalamic-cortical discharges. This was confirmed by Gellhorn (1958), Malmo (1959) and Sainsbury & Gibson (1964).

Jacobson's technique of relaxation is known as "Progressive Relaxation". It demands great determination and co-operation on the part of the subject. He first learns to recognize tension in certain isolated muscles and then attempts to go into negative direction or relaxation.

/Autogenic Training of Schultz:

Autogenic means self generated, self build or auto-suggestive training. This training was developed by a German physician, named, J.H. Schultz (1956, 1965). It is a combination of free-will or passive volitional aspect of yoga and Jacobson's technique of progressive relaxation. The passive volitional means to bring about the desired change in the body through auto suggestion and clear imagination. Autogenic relaxation can be accomplished either sitting or lying down and slowly repeating self suggestive phrases:

"My right hand is getting heavy".
"My right hand is getting warm".
"My heart is calm and regular"
"My breathing is calm and comfortable"
"My solarplexus is warm".
"My forehead is cool".

This method of relaxation is very popular among European athletes and it has been frequently found to be helpful during the period, just prior to competition and
after the activity. Muller-Hegeman (1956) had opined the autogenic relaxation technique might cause an increase in performance and energy potentials.

Genova (1973) investigated the effects of autogenic training on the psychical restoration after running. The indices were: emotional excitement, attention output and maximum motor rate of hand and legs movements. The measurements were taken by Tremograph, hand and foot tapping test and skin oxygen consumption. Psychical indices were recorded during the following four movements: (1) Before warming up, (2) Immediately after training, (3) After autogenous relaxation and passive response (lying supine) and (4) One hour after training. A subjective data (feelings) of the runners after relaxation techniques was also taken.

The restorative effect of five minutes autogenous relaxation was almost one and the same as the effect of one hour restoration. The capacity to perform maximum movement frequency increased after relaxation. Passive repose did not effect the immediate restoration on the maximum movement frequency.

Levarlet-Joye (1979) has investigated the motory capacity through autogenic relaxation. The objectives were to study both auditory and visual reaction, time, equilibrium, coordination and strength of hands and legs. The experiment was performed on 48 female subjects ranging from 19 to 22
years old and were divided into three groups of 16 subjects. The results were compared by analysis of variance.

The results showed the positive effect of relaxation on visual reaction time, concentration, manual coordination, skill and speed of movements (small muscle groups). Relaxation had, however, a negative effect on the strength of large muscle groups. Autogenic relaxation diminished the strength of legs as measured by dynamo-meter. Schultz (1956, 1965) had predicted that relaxation would alter the state of exciteability of the motor-neurone and that a stronger stimulation would be necessary to activate it. The study by Levarlet-Joye (1979) has thus substantiated that relaxation reduced the strength of large muscle groups.

Psychotonic Training of de Winter:

de Winter (1970) of France has developed the technique of relaxation for athletes based on autogenic training. This is currently known as Psychotonic training. Psychotonic training is a preferential experience in the muscular control allowing to obtain the vegetative control. It intends to be a specific psychosomatic preparation suitable for athletes. The training is planned to improve the recuperation after stress and in rest and by the reduction of the superfluous muscular contractions which interfere with the efficiency of athletic activities.
The training period of Psychotonic training consists of three months and is divided into two parts: (a) Preliminary stage or general sporting preparation; (b) Adaptation period to the particular sports, or transferential conditioning. The preliminary stage is based upon autogenous training of Schultz.

**Biofeedback Training of Green and Green:**

Green and Green (1970, 1973, 1973) studied the Schultz autogenic relaxation more extensively and combined it with newly developed biofeedback techniques. Their research studies showed that relaxation of voluntary control of involuntary internal states can be achieved in relatively easier manner through visual or auditory biofeedbacks than without them. Feedbacks of internal physiological states can be displaced by auditory, alpha rhythm, visual peripheral temperature and muscle tension records. This particular technique is known as autogenic feedback training. Experiments have shown that Yoga asanas facilitate this technique of relaxation.

Experiments with autogenic feedback training have shown reduction in muscle tension (EMG), increase in temperature of the hand (finger thermister); and increase in percentage of alpha rhythm (EEG). Such training proved to have clinical significance in case of migraine and tension headache, alcoholism, high blood pressure, Raynaud disease and insomnia.
Mahesh Yogi (1963) has simplified and streamlined a technique of yoga relaxation and meditation. He calls this technique as effortless meditation, because the technique could hardly be simpler. He stresses the importance of not thinking about or expecting results — that way, he says, the attention is undivided and the meditator will not fall victim to auto suggestion and only imagine that experience.

The technique consists of mentally repeating a word (Mantra) while sitting still. The lips and tongue should not move. A Yoga sitting posture is not expected if the meditator does not find it comfortable. The eyes are closed and the attention is turned inward. No mental force should be used; each time the mind is found to have wandered, the mantra is re-introduced.

TM as it is known for short, has steadily gained adherents in many countries. It has been tested experimentally. Benson (1976) has summarised the results of laboratory research on Transcendental Meditation:

(i) Heartbeat and breathing rates slow down.
(ii) Oxygen consumption and metabolic rate falls by twenty per cent.
(iii) The blood lactate level drops. This level goes up with stress and fatigue.
(iv) Skin resistance to electric current increase fourfold, a sign of relaxation.

(1) EEG readings of brain wave patterns shown increased alpha activity — again a sign of relaxation.
2.3 Maximal Work Output

The effect of recovery can be determined only through subsequent performance. The faster recovery of cardiovascular system during recovery is meaningless unless it improves the subsequent performance. Therefore, in the present investigation the pre and post recovery performance of the subjects was measured with the help of work performance on cycle ergometer. The criterion task was one minute cycling of supra-maximal intensity with 5 kgm resistance. The anaerobic work output was computed with the help of revolution counter.

2.3.1 Cycle Ergometer & Maximal (Anaerobic) Work

Bicycle ergometers are being used these days as a laboratory technique to assess the total work which can be performed by the subject within a specific time. Work output can be calculated by finding out the breaking force or resistance, multiplied by the total number of turns performed during a specific period.

According to Bobbert (1966), "an ergometer is an instrument for measuring work. This term usually indicates an apparatus enabling subjects to perform prescribed amount of work while physiological phenomena accompanying these performances can be measured with stationary instruments. In ergometry the physiological phenomena observed during exercise are related to the amounts of mechanical work per unit of time obtained by calculations or calibrations of the ergometer concerned."
Karpovich (1950) has described ergometer as a machine to measure the total work performed. Such machine usually provide a resistance against which the muscles have to work. The resistance is supplied by spring, weight, friction, or magnetic pull. Investigators use either a cycle ergometer or a treadmill.

Bicycle ergometers are of three types. The friction type, the magnetic brakes type and the Electric generator type. Most commonly used are the cycling (legs), the Cranking (arms) ergometers and the treadmill (walking and running).

Calculation of Work output

Different work physiologists have described different formulae for total work output depending upon the type of ergometers.

Karpovich (1950) and Ricci (1967) have mentioned the following formula for work output:

\[ W = FS \]

\( W \) = Work in kgm. \( F \) (resistance in kg scale units)

\( S \) = Distance travelled by flywheel rim (circumference x pedal revolutions)

According to deVries (1970) \( W = F (2\pi r)n \)

\( 2\pi r \) = the distance travelled by any point on the wheel in one revolution.

\( n \) = No. of revolutions during the work period.

Shepherd (1976) has used another formula for work output to condition heart and skeletal muscle with the help
of cycle ergometer.

\[ W = F \left(2\pi r\right) \frac{n^2}{A} = \text{kgm/min.} \]

\[ F = \text{Frictional loading in kg.} \]

\[ n = \text{The radius of the flywheel (metres)} \]

\[ a = \text{No. of teeth on pedal} \]

\[ A = \text{Teeth at the sprockets} \]

**Administration of Test:**

Dill (1966) Astrand & Rodahl (1970), Ryan and Allman (1974) have given valuable suggestions to conduct cycle ergometer tests:

1. At least two practice sessions must be given to the subjects for accurate results.

2. The seat should be adjusted for each individual. A saddle height that produces a slight bend of the knee just when the ball of the foot rest on the pedal and the leg is stretched.

3. Room temperature must be taken before the tests.

4. Time for food intake, smoking, coffee etc. and any mental stress such as examinations etc. must be taken into account.

5. Constant verbal encouragement ensures all out performance.

**Body Position and Performance:**

Faria Dix & Frazer (1978) undertook a study to determine whether the drop bar position or the top bar position assumed during cycling affected the performance.
It was concluded from the findings that maximum workout put could be obtained when the subject assumed the drop bar position than the top bar position.

Findings of the study further lent support to the conclusions drawn by Mcardle et al. (1973) and Pirnay (1972), who indicated that the blood flow in the quadriceps continuously rise, in intense exertion and that the amount of muscle mass engaged during work influences the VO₂ max (oxygen uptake). Evidently, the subjects were able to tolerate a longer work period, when a larger muscle mass (the arm, shoulder-girdle and lower back muscle) was used in drop bar position than the top bar position.

According to Craig (1960) the drop-bar position (15° lean) on the cycle ergometer resulted in a 4% increase in expiratory reserve volume.

**Criteria for Functional capacity:**

Several parameters have been used as evaluation criteria for the functional capacity of the body under muscular work. The most used physiological criteria are: oxygen intake, heart rate, blood pressure, oxygen pulse, blood lactate concentration, cardiac output, stroke volume, pulmonar y ventilation and heart volume.

The determination of the maximal oxygen intake is generally accepted by exercise physiologists as the most effective indicator of cardiovascular and respiratory
Numerous reports have appeared concerning measurements and interpretation of maximal aerobic power (McArdle, Katch, Pechar - 1970; Stamford - 1975; Stamford - 1976) and the effects of various training protocols on improvements in maximal aerobic functioning (Edwards - 1974; Eiseman and Gilding - 1974). In spite of great importance of anaerobic power in the field of sports, only few attempts have been found for studying the anaerobic power of different categories of sports. More work is needed about the capacity for anaerobic work and total work output in athletes and non-athletes, which apparently is a quite different individual characteristic (Hebbelinck - 1969; Verma, Mohindroo and Kansal - 1979).

In majority of research studies, anaerobic power has been calculated from scores on the Margaria test (Coleman et al. 1974; Shaverer - 1975 and Verma, Mohindroo and Kansal - 1979). The test consists of vertical raising the body to a prescribed limit (60 cms) divided by recorded time to reach the limit with the aid of photo electric cells and a Dekan timer; Sensitive to .01 of a second. This is expressed in kg-m/kg-sec.

Considering the research studies on cycle ergometer to determine the anaerobic functioning, the credit goes to Katch and Weltman (1973, 1974, 1975, 1977, 1978, 1979). The criterion task to determine the anaerobic functioning and
subsequent performance was on the basis of supra-maximal pedal revolutions on the cycle ergometer for one minute. The resistance was kept between 5 to 6 kg. During the active recovery procedure, the subject pedaled the cycle at 60 rpm with a lesser load of 1 kg. The anaerobic functioning was elaborated through revolution scores and cumulative scores. This was on the basis of 6 x 6 second time blocks. The revolution score and the cumulative scores were recorded after every sixth second and consecutively for 10 time blocks. The anaerobic power was measured on the basis of revolution scores accomplished during the first six seconds. The anaerobic capacity was measured on the basis of cumulative revolution scores at the end of 60th second or after 10 time block. To find out the total cumulative work output, the cumulative scores were converted into kgm-min.

Research studies by Belcastro and Bowen (1975), Weltman et al (1977); Katch et al. (1977) and Miyamura et al. (1978) have revealed that active recovery improves subsequent performance on bicycle ergometer due to enhanced lactate acid removal.

According to research study by Katch et al (1978) active recovery resulted insignificantly higher post recovery 6 x 6 seconds cumulative scores from 24th second onward than the passive sitting group.

According to Miyamura et al (1978) active recovery
should be able to maintain speed of revolutions (6 x 6 second revolution score) for a longer time, because of facilitation of venous return to the heart and prevention of pooling of the blood in the lower limbs.

According to research studies by Weltman et al. and Katch et al (1979), the speed of six x six seconds revolution score will gradually decrease and the decline will be pronounced within thirty seconds.

**Supra-maximal Training on Cycle-ergometer:**

Weltman et al (1978) examined the effects of high intensity, short duration of training on anaerobic power and anaerobic capacity on 19 college women age between 19.5 years.

Training consisted of two all out pedaling bouts on cycle ergometer (4.0 kg resistance, 40 second duration) separated by 10 minutes rest, three sessions weekly. The training sessions lasted for 12 weeks. The experimental group demonstrated significant improvement in anaerobic power output and anaerobic capacity.

Weltman et al (1978) investigated the effects of active vs. passive recovery from high intensity, short duration exercises on subsequent performance on bicycle ergometer. Result revealed significant recovery effects (lactate removal) and higher post recovery pedal revolutions in favour of active recovery.
In the present investigation the above mentioned procedure has been followed to find out the maximal (anaerobic) work output or performance.

2.3.2 Maximal Work output and Anthropometry:

Brouha and Radford (1960) have pointed out that there is a much higher correlation between the ability to perform hard exercise and the size of the individual than his age.

Experimental studies on cycle ergometer by Katch (1973) (1974); Katch, Weltman and Gray (1977); Weltman and Stamford (1978) have revealed a definite though moderate trend with individuals, with bigger legs and more total body muscles (lean body mass) to accomplish more work. Correlation of some anthropometric measures with work output were given as below:

<table>
<thead>
<tr>
<th>Measure</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lean Body Weight</td>
<td>.60</td>
</tr>
<tr>
<td>Knee Girth</td>
<td>.63</td>
</tr>
<tr>
<td>Thigh Girth</td>
<td>.52</td>
</tr>
<tr>
<td>Calf Girth</td>
<td>.65</td>
</tr>
</tbody>
</table>

Weltman and Katch (1975) used four skinfold (Triceps, Scapula, abdominal and iliac) and thigh circumference to estimate body density and body volume.

Equation:

\[ Y' = 0.8719(X_1) + 2629(X_2 - 9.685) \]

\[ Y' = \text{Body volume} \]

\[ X_1 = \text{Body weight} \]

\[ X_2 = \text{Thigh circumference} + \text{sum of four skinfold} \]

\[ \% \text{Body Fat} = (4.570 - (BW/\text{total body volume}) - 4.140) \]
Lean Body Weight = BW - (% fat x body weight)

Sloan (1967) estimated the body density, percent body fat, and lean body mass in young men aged 18-26 years and found out high correlation (r = 0.845) of two skinfold measures (front of the thigh and the inferior angle of the scapula). He found out a high correlation of two skinfolds (r = 0.845) with body density.

Equation:

\[
\text{Body Density} = 1.1043 - (0.00131 \times \text{sub scapula}) - (0.00132 \times \text{thigh}) \text{ gm/cc}
\]

\[
\text{Per cent body Fat} = (4.570/\text{Body Density} - 4.142)100
\]

\[
\text{Lean Body Mass} = \text{Body Weight} - (%\text{fat} \times \text{Body Weight})
\]

In the present study the above mentioned equation has been used to determine the effect of training on Lean Body Mass.

Several studies have been conducted (Parizkova-1961; Jokl-1962; Lambach-1969) to find out the effect of training on lean body mass. The investigators have found out an increase in lean body mass after training.

In the similar context there is a need to probe, whether four months of training in present investigation have a similar effect on lean body mass, or not.

2.4 Synthesis and Formulation of Hypotheses:

2.4.1 Synthesis of Review:

Cardio-Vascular responses during resting condition:
Variability in the cardiovascular responses to rest and exercises are influenced by many factors such as age,
sex, body size, body position (postures), time of recording, smoking, alcoholic intake, ingestion of food, emotions, body and environment temperatures and physical condition of the individual (Buskirk, 1974). It is, therefore, difficult to find out the exact and true resting values. According to Morehouse and Gross (1977), the resting heart rate of boys is generally between 80-84. The American Heart Association has mentioned 50-100.

The resting values of systolic, diastolic and pulse pressure varies according to different exercise physiologists (Reidman, 1950; Best and Taylor, 1967; Anderson, 1968; Karpovich and Sinning, 1971).

Range of systolic pressure = 110-140 (mm/Hg.)
Range of diastolic pressure = 60-90 (mm/Hg)
Range of pulse pressure = 30-55 (mm/Hg).

Exercise and training will reduce the resting heart rate and blood pressure. The reduction in heart rate can be due to vagal preponderance. Lowered heart rate also indicate increased stroke volumes (Fardy, 1971). It has been suggested (Clark, 1975) that prodicaria from training results from two factors: decrease in the intrinsic firing of the S.A. node and an increase in tonic vagal, cardio inhibitory activity.

Research studies on the effect of systolic and diastolic blood pressure during resting conditions have shown conflicting results. Some studies have revealed lower
systolic and diastolic pressures in trained and untrained (Knehr, Dill and Henfield, 1942; Taylor, 1971). Pollic and associates (1969), Penny and Wells (1975) found no significant change in trained and untrained.

Karpovich and Sinning have shown a typical range of systolic, diastolic and pulse pressure among trained sprinters and cyclists:

- Typical range of systolic = 105-120
- " of Diastolic = 70-80
- " of pulse pressure = 35-40

Merrit, Squires and Rodahl (1962), Cassino (1964), Garret, Sabic and Pangle (1965) and Baker (1968) found out that rope skipping, running on the spot and bench stepping improved the cardio-vascular efficiency of the subjects.

Smith and Stransky (1976) found out that riding a stationary bicycle develops cardio-vascular efficiency.

Rosentsweg and Burrhus (1975) concluded from the research study that improvement of cardio-vascular fitness can be elicited through intensity of training.

**Exercise Heart Rate:**

Devries has opined that rise in heart rate would be proportional to the work load per unit of time for intensity. Blood pressure would be effected by the type and intensity of exercise and physical condition of the subject. In rhythmic activities (cycling) the systolic would rise on the average
of 8 mm/Hg. For each increase in work load of two thousand foot-pounds per minute.

According to Karpovich and Sinning (1971), the systolic pressure showed increase in both athletes and non-athletes, but diastolic change slightly. The pulse pressure tended to increase and decrease with the systolic pressure.

Most of the exercise physiologists agree that training improves the exercise tolerance through reduction in exercise heart rate and systolic pressure with an increase of total work out put than pre-training.

Cardio-vascular Responses during Recovery:

The recovery is useful for visualizing regulatory responses (Adolph, 1974). According to Clarke (1975), recovery processes after exercise consisted of two components: one operating during the very early time period, the other controlling events later. There would be a spontaneous nature of the recovery following exercise during the early seconds, and by three minutes, a steady state be achieved with no further gains.

According to deVries (1970), Karpovich and Sinning (1971), the heart rate for the first two and three minutes after exercise decrease almost as rapidly as it was increased. After this initial rapid decrease further decline in heart rate occurred more slowly at a rate, roughly related to the
intensity and duration of the work. Among healthy individuals, the recovery rate was faster. The heart rate recovery speed (deceleration index) is greater after training and a sure criterion of training (Ardisson et al, 1973).

According to Brouha (1960), the resting blood pressure might be established after 10 minutes of rest. According to Reidman, in speed exercises the return to normal would be slow. Best and Taylor (1967) found return of blood pressure to resting level from 1-4 minutes after light exercise.

Investigation of Shapiro, Shoenfeld and Shapiro (1976) showed that recovery heart rate at the very beginning of the recovery period was mostly influenced by the heart rate at work and the Vo$_2$ maximum. It was opined that higher stroke volume during the recovery period could be one of the factors to influence the recovery heart rate.

**Re recuperative Procedures and Cardio-Vascular Recovery:**

Exercise physiologists, deVries (1970), Budgetchell (1976), Molner (1976), Katch et al (1977, 1978) and Weltman (1977, 79) have stressed faster cardio-vascular recovery through active recovery (walking, slow jogging and slow cycling). The enhancement of cardio-vascular recovery may be attributed to acceleration of venous return and removal of lactate during recovery by moderate aerobic exercise. However, recent study by Katch et al (1978) have pointed out that if removal of the lactic acid is considered as recovery index, then
active recovery is the best, in case heart rate is taken as the index then there is no significant difference between active and passive recovery techniques. Probably status of physical fitness is the main deciding factor. In contrast Henry and Demoor (1951) and Royce (1969) indicated superiority of passive recovery to cardio-vascular recovery and to the largest decrease of O₂ consumption than the active recovery.

Relaxation Techniques and Cardio-vascular Recovery

Schultz (1956 and 1965), Genova (1972) and Levarlet (Joye 1979) have shown experimentally that autogenic technique of relaxation has proved to be most effective technique of relaxation for cardio-vascular recovery than passive rest. The capacity to perform maximum movement frequency increased through autogenic relaxation.

Romanowski (1969 and 1971), Datey et al (1969), Dhanaraj (1974), Udupa (1978), Mall, Chaudhry and Giri (1978), Kocher (1979) have concluded from their research studies that yogic asanas and pranayama have proved to be an effective method of relaxation to hasten the process of recovery after exercise. The practice of savasana and pranayama influence the parasympathetic system and improved the vagal tone. Savasana decreases the blood pressure and the knee jerk. It was hypothesized that diaphragmatic breathing during savasana reduces the frequency and intensity of the
proprioceptive and enteroceptive impulses. These impulses influence hypothalamous, which reduces the blood pressure (Chhina & Singh, 1975).

Through yogic practices, the ability to control the autonomic nervous system is achieved. There is objective evidence that the practitioners could reduce oxygen consumption and metabolic rate through voluntary relaxation of the skeletal musculature (Rele, 1927 and Chhina 1975).

Dhanaraj (1974) found out that savasana was more effective method for pulse recovery after exercise than 5 B x plan.

Levarlet-Joye (1979) investigated the motory capacity through autogenic relaxation. He found out a negative effect on the strength of large muscle groups. Autogenic relaxation diminished the strength as measured by dynmometer.

Weltman, Stemford, Maffatt and Katch (1977) examined the effects of active and passive recovery from high intensity short duration exercise on lactate removal and subsequent performance. The results revealed that both active recovery and 20 minutes passive lying recovery resulted in enhanced and greater subsequent exercise performances on a cycle-ergometer.

According to the research studies by Hatch et al (1978) active recovery resulted in significantly higher post recovery
6 x 6 seconds cumulative scores from 24 second onward than the passive sitting group.

Research studies by Belcastro and Bowen (1975), Weltman et al (1977), Katch et al. (1977) and Miya Mura et al (1978) have revealed that active recovery improves subsequent performance on bicycle ergometer due to enhanced lactate acid remover.

According to Miya Mura et al (1978) active recovery should be able to maintain speed of revolutions (6 x 6 second revolution score) for a longer time, because of facilitation of venue return to the heart and prevention of pooling of the blood in the lower limbs.

According to research studies by Weltman and Katch et al (1979) the speed of six x six seconds revolution score will gradually decrease and the decline will be pronounced within thirty seconds.

Weltman et al (1978) examined the effects of high intensity, short duration of training (with cycle ergometer) on anaerobic power, capacity and work output, the training period lasted twelve weeks. There was significant improvement in anaerobic power, capacity and total work output.

The passive lying and yogic relaxation will show less 6 x 6 seconds revolution scores immediately after recovery than the active and passive sitting groups.
Anthropometric measures and Work Performance:

Brouha and Radford (1960), Katch, Weltman and Gray (1977) Weltman and Stamford (1978) have revealed a definite though moderate trend with individuals, with bigger legs and more lean body mass to accomplish more work.

2.4.2 Hypotheses:

In order to achieve the objectives of the study, hypotheses were framed on the basis of the literature reviewed in the preceding pages. They are stated under following headings:

(i) Cardiovascular adaptation to training during test and exercise stress.

(ii) Cardiovascular responses to Active, Passive and Yogic Recovery Techniques.

(iii) Recovery techniques and subsequent maximal anaerobic work output.

I. Cardiovascular Adaptation to training during Rest and Exercise Stress:

The cardiovascular responses within the context of the present investigation consists of: Heart Rate, Systolic and Diastolic blood pressure and pulse pressure. All the subjects belonging to different recovery groups (Active sitting, passive sitting, passive lying and Savasana) underwent short duration exercises interspaced with the recovery techniques.
Hypothesis pertaining to training effects on cardiovascular responses are formulated on the basis of research evidences as evinced in the synthesis of review. Results of the studies have indicated that training will improve the cardiovascular efficiency during resting conditions resulting in reduction of heart rate, systolic and diastolic pressures. Research studies on the effect of training on resting pulse pressure are however, scanty. Thus the hypotheses in this particular variable are inferential derivation based upon the effect of short intermittent intensive training on cardiovascular adaptation at a younger age group. The cardiovascular adaptation is more pronounced at a younger age as compared with the older group (Christensen-1960; Ika.i-1969).

The exercise physiologists have further purported that training improves the exercise tolerance through reduction in exercise heart rate with a concomittant increase in total work output.  

Hypotheses: 

(i) Training reduces the resting heart rate, systolic and diastolic blood pressures of active sitting, passive sitting, passive lying and yoga (Savasana) groups.

(ii) Among the four groups; active sitting, passive sitting, passive lying and yoga; yoga group shows maximum reduction in resting heart rate, systolic and diastolic pressures.
Training increases the resting pulse pressure of the active sitting, passive sitting, passive lying and yoga groups.

Among the four groups; active sitting, passive sitting, passive lying and yoga; yoga group shows highest increase in pulse pressure.

Training improves the exercise stress tolerance of all the four groups through reduction in exercise heart rate and simultaneous increase in the total cumulative work out.

Among the four groups: active sitting, passive sitting, passive lying and yoga; active sitting shows maximum heart rate tolerance to exercise stress and simultaneous increase in the total work output.

II. Cardiovascular Responses to Active, Passive and Yogic Recovery Techniques

In this area a number of testable hypotheses can be derived on the basis of research studies pertaining to four recovery procedures.

(i) Active recovery while cycling with a reduced load (ARS).

(ii) Passive recovery while sitting on a cycle (PRS).

(iii) Passive recovery lying (PRL).

(iv) Yogic (Savasana) Recovery lying (YRL).
The bulk of research studies signify that training will increase the speed of recovery, and the pattern of recovery will be a rapid decline during the first three minutes, then a plateau and a slow decline.

The blood pressures (systolic, diastolic and pulse pressures) will decline rapidly, and may regain resting levels by ten minutes of recovery period. Savasana relaxation influences the hypothalamus and this technique may have pronounced effect on the reduction of heart rate, systolic, diastolic and pulse pressures; than the other recovery procedures:

Hypotheses:

(i) Training reduces the recovery heart rate of all the recovery techniques during ten minutes of recovery period.

(ii) Among the four recovery techniques, active sitting, passive sitting, passive lying and savasana; savasana shows the maximum deceleration.

(iii) The heart rate deceleration index pattern depicts a rapid deceleration during the first three minutes.

(iv) Of the four recovery techniques, active sitting, passive sitting, passive lying, and yoga (savasana), savasana depicts a higher deceleration index during the first three minutes.
(v) Training reveals a faster decline to systolic, diastolic and recovery pulse pressures among all the recovery techniques than the pre-training.

(vi) Among the four techniques, active sitting, passive sitting, passive lying, yoga (savasana); the savasana technique shows a highest decline in systolic, diastolic and pulse pressures at all stages of measurement.

(vii) Of the four recovery techniques: active sitting, passive sitting, passive lying and savasana; the savasana relaxation technique helps to reduce the systolic, diastolic and pulse pressures to conventional resting level after ten minutes of recovery.

III. Recovery Techniques and Subsequent Maximal Work Output

The hypotheses are formed under four sub-divisions:

(A) Training effects on six-by-six seconds Revolution Scores.

(B) Training Effects on six-by-six seconds, cumulative scores.

(C) Training Effects on Total Cumulative Work output.

(D) Training effects on selected Anthropometric Measures and Pre-recovery total cumulative work output.

Training Effect on six x six seconds Revolution and Cumulative Scores:

Miyamura et al (1978) have concluded from their
research study, that active recovery should be able to maintain the speed of 6 x 6 seconds revolution scores for a longer time than the passive sitting. The passive lying and savasana recovery techniques will show less 6 x 6 seconds revolution scores immediately after recovery, due to deep relaxation effect (Levarlet Joye-1979). The active recovery showed higher 6 x 6 seconds cumulative scores than passive recovery from 36th seconds onward (Katch et al - 1978).

Following hypotheses are framed on the basis of synthesis of literature.

(A) Training Effect on six by six seconds Revolution scores:

(i) Of the four recovery techniques, active sitting, passive sitting, passive lying and savasana; savasana shows the lowest composite post training speed of revolution at the 6th second time block than the pre training.

(ii) The composite effect of post training pre and post recovery on the speed of revolutions is higher upto 24th second among all the recovery techniques, than the pre training.

(iii) Among the four recovery techniques, active sitting, passive sitting, passive lying and savasana; active sitting shows highest composite post training speed endurance scores than the pre-training.
(iv) The post training pre-recovery 6 x 6 seconds revolution scores increases in all the four recovery techniques up to 36th second than the pre-training pre-recovery scores.

(v) Of the four recovery techniques, active sitting, passive sitting, passive lying and savasana; active sitting gains the highest post training pre-recovery speed revolution scores after 36th second onward than the pre-training pre-recovery.

(vi) Among the four recovery techniques, active sitting, passive sitting, passive lying and savasana; savasana shows the highest post training post recovery speed endurance than the pre-training post recovery.

B) Training Effect on 6 x 6 seconds Cumulative Scores:

(i) The intra-group composite effect of post training pre and post recovery on 6 x 6 seconds cumulative scores shows higher scores only by by active sitting and yoga recovery groups than the pre-training pre and post-recovery scores.

(ii) Of the four recovery techniques, active sitting, passive sitting, passive lying and savasana; active sitting shows highest composite post training 6 x 6 seconds cumulative scores than the pre training.
(iii) The post training pre-recovery 6 x 6 seconds cumulative scores increases in all the four recovery groups than the pre training pre-recovery scores.

Among the four recovery groups, active sitting, passive sitting, passive lying and savasana; savasana gains the highest post training post recovery 6 x 6 seconds cumulative scores than the pre training post recovery.

C) Training Effects on Total Cumulative Work output

There is research evidence by Weltman et al. (1978) and Katch et al. (1978) that short bouts of high intensity exercise and the active recovery technique had significantly improved the anaerobic power, anaerobic capacity or total cumulative work output of the subjects. Active recovery proved to be more effective than passive sitting or lying. The restorative effect of five minutes of relaxation (lying) have shown increased maximum movement frequency than one hour passive rest. Since anaerobic capacity measures the total cumulative work, only total work output has been considered. On the basis of research studies following hypotheses are putforth.
Hypotheses

(i) Among the four recovery groups, the composite effect of post-training pre and post recovery cumulative work output is higher in active sitting and yoga Osavasana) groups than pre-training pre and post recovery cumulative work output.

(ii) Between the two sitting techniques, active sitting and passive sitting; active sitting performs higher composite post training cumulative work output scores than the pre-training.

(iii) Between the two lying techniques, passive lying and savasana, savasana technique shows higher composite post training cumulative work output than the pre-training.

(iv) Of the four recovery techniques, active sitting, passive sitting, passive lying and savasana, active sitting shows highest composite post training cumulative work output scores than the pre-training.

(v) The post training pre-recovery cumulative work output scores increases in all the four groups, than the pre-training pre-recovery scores.

(vi) Among the four recovery techniques, active sitting, passive sitting, passive lying and
savasana, the active sitting gains the highest post training pre-recovery cumulative work output score than the pre-training pre-recovery.

(vii) The post training post recovery cumulative work output score increases in all the four experimental recovery techniques than the pre-training post recovery scores.

(viii) Between the two sitting techniques, active sitting and passive sitting, active recovery shows higher post training post recovery cumulative work output scores than the pre training post recovery.

(ix) Between the two lying recovery techniques, passive lying and savasana; savasana elicits higher post training post recovery cumulative scores than the pre training post recovery.

(x) Of the four recovery techniques, active sitting, passive sitting, passive lying and savasana; savasana gains the highest post training post recovery cumulative work output scores than the pre-training post recovery.

D) **Training Effects on Selected Anthropometric Measures and Pre-recovery Total Cumulative Work Out-put**

Brouha and Radford (1960); Katch, Weltman and Gray (1977) Weltman and Stamford (1978) have revealed a definite though moderate trend with individuals, with bigger legs and
more lean body mass to accomplish more work.

Hypotheses:

(i) Training increases the circumference of thigh, knee and calf of all the four groups.

(ii) Training increases the total three girths of all the four groups.

(iii) Among the four groups, the group possessing largest measurement of total three girths shows highest post training pre-recovery total cumulative work output scores.

(iv) Training increases the lean body mass of all the four groups.

(v) Among the four groups, the group possessing highest amount of lean body mass shows highest post training pre-recovery in total cumulative work output (kgm) than the pre training.