CHAPTER II

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The present chapter covers the available literature pertaining to the studies made on various aspects of resistance training. The review of literature has been collected from a number of pertinent studies undertaken by the physical educationists, sports scientists and sports medicine specialists on resistance training. Considering the purpose of the present study the reviews have been classified into the following sub-sections:

1. Physical parameters pertaining to muscular strength and muscular endurance.

2. Anthropometrical parameters pertaining to percent body fat and girth.

3. Haemotological parameters pertaining to haemoglobin and red blood cells.

4. Biochemical parameters pertaining to blood glucose, total protein, albumin, globulin, blood cholesterol and blood lactate.
PHYSICAL VARIABLES

The resistance training is considered as one of the most effective methods available for maintaining and increasing lean body mass and improving muscular strength and endurance. It also significantly improves many health factors associated with the prevention of chronic diseases. These health benefits can be safely obtained by most segments of the population when prescribed with appropriate resistance exercise programmes. The programme should be tailored to meet the needs and goals of the individual and should incorporate a variety of exercises performed at a sufficient intensity to enhance the development and maintenance of muscular strength, endurance and lean body mass.

Studies Related to Muscular Strength and Muscular Endurance

Recent literature in the area of muscular strength and muscular endurance are reviewed below.

Mazzetti et al., (2000) studied the effect of Supervised Training (SUP) versus Unsupervised Training (UNSUP) in twenty moderately trained men aged 24 to 26 years. Both groups performed identical, linear, periodized resistance training programmes consisting of preparatory phase with 10 to 12 repetitions of 1 RM, hypertrophy phase with 8 to 10 repetitions of 1 RM,
strength phase with five to eight repetitions of 1 RM and peaking phase with three to six repetitions of 1 RM using free weight and variable resistance machine exercises. Subjects were tested for maximal squat and bench press strength (1 RM), squat jump power output, bench press muscular endurance and body composition prior to and twelve weeks after training.

Mean training loads (kg per set) per week were significantly greater in the SUP group than the UNSUP group at weeks seven through eleven for the squat and weeks three and seven through twelve for the bench press exercises. The rates of increase of squat and bench press kg per set were significantly greater in the SUP group. Maximal squat and bench press strength were significantly greater at week twelve in the SUP group. Squat and bench press 1 RM and mean and peak power output increased significantly after training in both groups. Relative local muscular endurance (80% of 1RM) was not compromised in either group despite significantly greater loads utilised in bench press muscular endurance testing after training. Body mass, fat mass, and fat-free mass increased significantly after training in the SUP group.

Taaffe et al., (1996) studied the effects of 52 weeks resistance training of either a control, high intensity or low intensity on thigh muscle strength, fiber cross sectional area and tissue composition in 65 to 79 year old healthy women. Exercise regimens consisted of three sets of leg press, knee extension
and knee flexion exercises for three days per week, at either 80% of one repetition maximum for seven repetitions of high intensity or 40% of 1 RM for 14 repetitions of low intensity. Dynamic muscle strength was evaluated by 1 RM, thigh lean tissue mass, fat mass, and bone mineral density by dual energy X-ray absorptiometry and fiber cross sectional area of vastus lateralis muscle by histomorphometry.

Muscle strength increased, on average by 59.4 and 41.5 percent for high intensity and low intensity groups, respectively compared to 1.3 percent in control group. Type I fiber cross sectional area increased over time in both exercise groups with a trend for increased type II area. There was no significant effect of either exercise programme on thigh tissue composition, except for bone mineral density at the middle third of the femur, where low intensity and control groups experienced a decline of 2.2 and 1.8 percent, respectively, while high intensity maintained bone mineral density (1.0 percent). Both training programmes produced significant gains in thigh muscle strength associated with fiber hypertrophy, although these did not translate into appreciable alterations in thigh tissue composition.

Chrusch et al., (2001) studied thirty older men who received creatine supplementation or placebo and observed the effect of creatine supplementation combined with resistance training on muscular performance and body composition. Creatine supplementation consisted of 0.3 grams per
Kg body weight for the first five days (loading phase) and 0.07 grams per Kg body weight thereafter. Both groups participated in resistance training for 36 sessions, three times per week, three sets of 10 repetitions for a total of 12 exercises. Muscular strength was assessed by one repetition maximum (1 RM) for leg press, knee extension, and bench press. Muscular endurance was assessed by the maximum number of repetitions over three sets separated by one minute rest intervals at an intensity corresponding to 70% baseline 1 RM for bench press and 80% baseline 1 RM for knees extension and leg press. Creatine supplementation, when combined with resistance training increased lean tissue mass and improved leg strength, endurance and average power in men with mean age of 70 years.

Faigenbaum et al., (1999) studied the effects of low repetition - heavy load resistance training programme and a high repetition - moderate load resistance training programme on the development of muscular strength and muscular endurance in 11 girls and 32 boys between the ages of 5.2 and 11.8 years. The resistance training was conducted twice a week for eight weeks, children performed one set of six to eight repetitions with a heavy load numbering fifteen or one set of 13 to 15 repetitions with a moderate load numbering sixteen on child size exercise machines. Children in the control group numbering twelve did not do resistance training.
One repetition maximum (1RM) strength and muscular endurance were determined on the leg extension and chest press exercises. One RM leg extension strength increased 31.0 and 40.9 percent respectively in low repetition heavy load and high repetition moderate load groups. Leg extension muscular endurance significantly increased in both the groups. But the gains were significantly higher in high repetition - moderate load training (13.1 ± 6.2 repetitions) than the low repetition - heavy load training (8.7 ± 2.9 repetitions). On the chest press exercise, only the high repetition - moderate load exercise group made gains in 1 RM strength (16.3%) and muscular endurance (5.2 ± 3.6 repetitions) that were significantly greater than in the control subjects. The findings supported the concept that the muscular strength and endurance can be improved during the childhood years and favour the prescription of higher repetition - moderate load resistance training programmes during the initial adaptation period.

Jones et al., (2001) studied thirty NCAA Division I baseball players assigned to either a low resistance (40 - 60% of 1 RM) training or a high resistance (70 - 90% of 1 RM) training, to compare the changes in velocity - specific adaptations. Both the training groups intended to maximally accelerate each repetition during the concentric phase by individual maximal concentric acceleration. The training consisted of 10 weeks with four training sessions per
week using basic exercises. Peak force, velocity and power were evaluated during set angle and depth jumps as well as weighted jumps using 30 and 50% of 1 RM squat. One RM’s were also tested.

Percentage gains suggest that the combined use of heavier training loads (70 -90% 1 RM) and individual maximal concentric acceleration tend to increase peak force in the lower body, leg and hip extensors. The combined uses of lighter training loads (40 - 60% 1 RM) and individual maximal concentric acceleration tend to increase peak power and peak velocity in the lower body leg and hip extensors. The high resistance group improved squats more than the low resistance group. The results of this study support the use of a combination of heavier training loads and individual maximal concentric acceleration to increase 1 RM strength in the lower body of resistance trained athletes.

Keeler et al., (2001) studied 14 healthy sedentary women, 19 - 45 years of age grouped as traditional Nautilus style group or super slow strength training group to assess the muscular strength, body composition, aerobic capacity and cardiovascular endurance. The training was conducted three times per week for ten weeks. Measurements were taken both before and after training, which included a maximal incremental exercise test on a cycle ergometer, body composition, and 1 RM tests on eight Nautilus machines.
Both groups increased their strength significantly on all eight exercises, whereas the traditional group increased significantly more than the super slow group on bench press (34% Vs 11%), torso arm (anterior lateral pull down) (27% Vs. 12%), leg press (33% Vs 7%), leg extension (56% Vs. 24%) and leg curl (40% Vs. 15%). Thus, the traditional group’s improvement in total exercise weight lifted was significantly greater than that of the super slow group after training (39% Vs. 15%). Exercise duration on the cycle ergometer and work rate significantly improved for both groups. No significant differences were found in the body composition or additional aerobic variables that were measured. Both strength training protocols produced a significant improvement in strength during a ten weeks training period, but the traditional protocol produced better gains in the absence of changes in percentage of body fat, body mass index, lean body mass and body weight.

Carroll et al., (2001) opined that the resistance training is accompanied by changes within the nervous system that play an important role in the development of the strength. Many elements of the nervous system exhibit the potential for adaptation in response to resistance training, including supraspinal centres, descending neural tracts, spinal circuitry and the motor end plate connections between motor neurons and muscle fibers. Yet the specific sites of adaptation along the neuraxis have seldom been identified
experimentally and much of the evidence for neural adaptations following resistance training remains indirect. Uncertainty exists regarding the manner in which the resistance training impacts upon the control and execution of functional movements. To demonstrate that resistance training is likely to cause adaptations to many neural elements that are involved in the control of movement, a small number of experiments were reviewed.

Hunter et al., (2001) studied the effects of high resistance training three times per week at 80% of 1 RM and variable resistance training with three times per week (once weekly training at 80%, 65% and 50% of 1 RM) in 28 men and women over the age of 60 years. Eight volunteers served as controls. Before and after 25 weeks of training, body composition was measured by densitometry, strength by isometric tests and difficulty in performing daily activity tasks by measuring heart rate, oxygen uptake, electromyography and perceived exertion. In addition, 1 RM strength was measured every 25 days throughout the six months of training. The results showed that the control group did not significantly change in any of the selected parameters. No significant change in body weight occurred for any group. However, the high resistance and variable resistance groups increased fat free mass. Similarly, both training groups increased strength significantly without significant difference in change. No significant change in oxygen uptake occurred during
daily activity tasks. However, there was a significant time effect for heart rate and perceived exertion. Despite similar increases in strength and fat free mass, the variable resistance group experienced a decreased difficulty in performing the carry task more than the high resistance group. These data suggested that larger improvements in daily activity tasks may be achieved if frequency of high resistance training was less than three times per week.

Winett and Carpinelli, (2001) observed that the resistance training enhanced cardio respiratory fitness and has profound effects on the musculo skeletal system, prevents osteoporosis, sarcopenia, lower-back pain and other disabilities. More recent research showed that the resistance training may positively affect risk factors such as insulin resistance, resting metabolic rate, glucose metabolism, blood pressure, body fat and gastro intestinal transit time which are associated with diabetes, heart disease and cancer. The benefits of resistance training were likely to be obtained in two 15 to 20 minutes training involving precise controlled movements for each major muscle group and did not require the use of heavy resistance.

Chilibeck, et al., (1996) conducted a weight training programme in twenty young women and ten women served as the control group. They were subjected to upper and lower body exercises twice a week for twenty weeks. The training resulted in significant increase in arm curl (72%), bench press
(33%) and leg press (23%) lifting performance. The data indicated that a resistance training programme that effectively increased strength and lean tissue mass in young women may fail to increase bone mineral density over a 20 week training period.

Warrington, et al., (2001) studied sixteen male tug of war athletes with a mean of 34 years to determine the aerobic power (Vo2 max) body composition, strength, muscular power, flexibility, and biochemical profile. For comparative purposes, data were analysed relative to normative data for our center and to a group of 20 rugby forwards from the Irish international squad. A composite measure of strength derived from (sum of dominant and non-dominant grip strength and back strength) / lean body mass yielded a strength / mass ratio that was 32 percent greater for the tug of war group than the rugby group.

Dynamic leg power was lower for the tug of war group than the rugby forwards (151.6 watts V 105 watts) respectively; Leg flexibility was 25.4 cms for the tug of war group. Back flexibility was 28.6 cms which was lower than the rugby forwards 34.2 cms. The blood chemistry and haematology were normal. Packed cell volume, haemoglobin concentration and erythrocyte volume were lower in the tug of war group than in the rugby players.
Taafe, et al., (1994) investigated whether the age related changes in body composition, muscle strength and somatotrophic function can be limited by resistance training in older individuals. For this eighteen healthy elderly men in the age group of 65 to 82 years, initially underwent progressive weight training for 14 weeks to invoke a trained state. The subjects were then, randomized to receive either 0.02 mg/kg body weight per day recombinant human Growth Hormone (rh GH) or placebo given subcutaneously, while undertaking a further 10 weeks of strength training. Sequential measurements were made of muscle strength (one repetition maximum), body composition (dual energy X-ray absorptiometry) and circulating levels of insulin - like growth factor - I (IGF-I) and IGF - binding protein - 3. For each exercise, strength increased for both groups through 14 weeks of training, with little improvement thereafter. Increases in muscle strength ranged from 24 to 62 percent depending on the muscle group. Body weight did not change in either group, but lean body mass increased and fat mass decreased in the rh GH group. Supplementation with rh GH does not augment the response to strength training in elderly men.

Giorgi, et al., (1999) studied the effect of steroid testosterone enanthate in upper body strength, body composition and health in 21 male weight training subjects. They were randomly assigned in a double blind
method to either a 3.5 mg$^{-1} \times$ kg$^{-1}$ testosterone enanthate ($n = 11$) or placebo ($n = 10$) weight training group. They were monitored during a 12 week administration phase and a subsequent 12 week follow up phase. The subjects were tested on a number of strength and size measurements, while having their health monitored. The results revealed that the testosterone/weight training group improved significantly more than the placebo/weight training group during and immediately after the administration phase on a one repetition maximum bench press.

The body composition, body weight, arm girth and rectus femoris circumference all increased significantly greater in the testosterone enanthate group compared to the placebo. Furthermore, the abdomen skinfold showed significant decrease in the testosterone enanthate group compared to the placebo group at post testing, follow-up mid testing and the follow up post testing occasions. Moderate doses of testosterone enanthate combined with weight training can result in short term significant changes in upper body strength and body composition with corresponding changes to baseline health in same individuals.

Ades, et al. (1996) studied the effect of resistance training programme on walking endurance in a healthy population group of more than 65 years of age. An increased sub maximal walking endurance was observed
in weight training group while no change could be observed in control group. Based on this study, it was concluded that the resistance training programme for a duration of three months improved both leg strength and walking endurance.

McCartney, et al., (1996) conducted a two year weight training programme in 60 to 80 years aged healthy subjects. They concluded that the long term weight training programme proved to be safer and well tolerated mode of exercise, increasing strength and endurance in cycling, walking and stair climbing while no significant change could be observed in bone mineral density.

Based on the available literature in the area of research on the muscular strength and muscular endurance, it is concluded that there was significant increase in muscular strength and endurance due to resistance training (Mazzaeeti, et al., 2000; Keeler, et al., 2001; Winett and Carpinelli., 2001; Chiliback, et al., 1996; Taaffe, et al., 1994 and McCartney, et al., 1996). The maximum muscular strength gain was obtained in high intensity resistance training (Taaffe, et al., 1996; Jones, et al., 2000; Hunter, et al., 2001). The muscular strength could be effectively achieved with heavy load and low repetition of resistance training and the muscular endurance could be effectively achieved with moderate load and high repetitions (Faigenbaum,
et al., 1999). The creatine supplementation when combined with resistance training improved muscle strength and endurance (Churuch, et al., 2001).

ANTHROPOMETRICAL VARIABLES

Anthropometry is the measurement of the body size, namely, height, weight and proportions including overall girth and limb girth. The anthropometric measures are reliable test procedures and is a great asset in assessing the fitness levels and evaluating changes over a period of time.

Studies Related to Percent Body Fat and Girth

Various studies related to the percent body fat and girth are reviewed below.

Percent Body Fat

Calder, et al., (1994) studied thirty women comprising 10 women in each group as whole routine training, split routine training, and control group. The whole routine group did four upper and three lower body exercises on two other days of the weeks. The single maximal weight lift (1 RM) increased (whole routine training / split routine training) 54/69%, 33/32% and 21/22% in arm curl, bench press and leg press exercises, as did arm (10/9%) and trunk (3.4/2.7%) lean tissue mass as measured by dual energy X-ray absorptiometry.
Leg lean mass increased significantly only in whole routine group (4.9% Vs 1.7% in split routine training). Whole body lean tissue mass increased (4.1/2.0%) and whole body percent fat (-1.1 to 1.3%) decreased with training. It was concluded that in healthy young women, whole and split weight training routines produce similar results over the first five months of training.

Prabhakaran, et al., (1999) studied the effect of a supervised, intensive (85% of RM) on a 14 week resistance training programme on lipid profile and body fat percentage in 24 healthy, sedentary, premenopausal women of 27 years of age. The subjects were grouped into a non-exercising control group and a resistance exercise training group. The resistance exercise training group attended 45 - 50 minute training (85% of 1 RM), three days a week on non-consecutive days for 14 weeks. The control group did not take part in any structured physical activity. Two way analysis of variance with repeated measures showed significant increase in strength (1RM), decrease in total cholesterol, low density lipoprotein and body fat percent. No differences were seen in triglycerides and high density lipoprotein cholesterol. No changes were found in any of the measured variables in the control group. The findings suggested that the resistance training had a favourable effect on lipid profile and body fat percentage in healthy, sedentary premenopausal women.
Gettman, et al., (1982) studied the effects of a programme of combined running and weight training with a programme of circuit weight training in thirty six females and 41 males. The training groups participated in a 12 week programme for three days per week. Three circuits of ten weight training exercises were completed with 12 to 15 repetitions performed in 30 seconds at 40% of one repetition maximum at each station. The 30 minutes combined running and weight training programme included 30 seconds of running at an indoor track following each circuit weight training station, whereas the 22.5 minutes circuit weight training programme included a 15 seconds rest period between stations.

The combined running and weight training groups had a significant (+17%) increase in Vo2 max (females 30.5 - 35.7 ml kg.1 min. 1 and males 39.7 - 46.3 ml kg - 1 min - 1) and strength (female + 24% and males + 21%) and a significant decrease in body fat percentage (females - 3.2% and males - 4.1%). The circuit weight training groups also increased significantly in Vo2 max (+ 12%) and strength (+ 17%) and decreased in body fat (-3.0%). The controls did not change significantly in any variable. Statistically, one training programme was not shown to be superior to the other, thus, both programmes of combined running and weight training and circuit weight training were effective in improving measures of physical fitness.
Barnard. et al., (1979) studied 13 sprint (age 41-58 years) and 13 distance athletes. The mean Vo₂ max value for the distance runners was 54.4 ± 3 ml. Kg⁻¹ min⁻¹ compared with 47.2 ± 2 ml kg min for the sprinters. The highest Vo₂ max (71.0 ml.kg⁻¹.min⁻¹) was obtained on a 45 year old distance runner while the lowest 27.3 ml kg min) was obtained on the oldest (78 years) distance runner. Vo₂ max decreased by 34.5% from age 40 to 70 in the distance runner in spite of continued training that ranged from 40 to 20 miles per week. Percentage of body fat was 16.5 ± 0.5 for the sprinters and 18.0 ± 1.1 for the distance runners. Serum cholesterol values were 218.7 ± 8.7 and 203.0 ± 13.8 ml/dl, while triglyceride values were 101.5 ± 8.2 and 84.1 ± 9.3 mg/dl for the sprint and distance groups, respectively. These data indicated that, Vo₂ max decreased significantly with aging despite the continuation of long distance training. Percent body fat and serum lipid levels were significantly lower in these athletes compared to those for sedentary adults, suggesting a protective effect against coronary heart disease.

The literature reviewed in the area pertaining to the percent body fat, concluded that, in healthy young women, both whole and split weight training routines reduced the percent body fat. (Calder, et al., 1994) Supervised intensive (85% of 1 RM) resistance training decreased body fat percentage and total cholesterol. (Prabhakaran, et al., 1999). Both, the combined running and
weight training, and the circuit weight training programmes reduced the body fat percentage (Gettman, et al., 1982). The percent body fat and serum lipid levels were significantly lower in the distance and sprint runners when compared to the sedentary adults, suggesting a protective effect against coronary heart disease (Barnard, et al., 1979).

Girth

Mayhew, et al., (1991) studied the relationship between structural dimensions and bench press performance in 140 college males / male students of the 14 weeks of strength and aerobic endurance training. Anthropometric dimensions included upper arm and chest circumferences, upper and lower arm lengths, shoulder and hip widths, percent fat and height. Arm muscle cross-sectional area was calculated from upper arm circumference corrected for triceps skinfold. Multiple regression analysis selected upper arm cross sectional area, percent fat and chest circumference as the best items to predict bench press strength \((R = 0.833; \text{SEE}=11.6 \text{ kg})\). The results of this study suggested that bench press performance was related to structural dimensions in males and that extensive strength training may alter the relationship between size and strength.

Spenst, et al., (1993) documented on limb girths and skinfold thickness by measuring in 62 male athletes (aged 17-38 years) and 13 non-athletic males
(aged 22-36 years). The muscle mass was calculated in both athletes and nonathletes. The athletes were classified as gymnasts numbering ten, basketball players numbering ten, body builders numbering ten, track and field power athletes, numbering twelve, track and field long sprinters, numbering ten and distance runners numbering ten. The muscle mass ranged from 38.4 kg for the distance runners to 58.7 kg for the body builders. The muscle mass as a percentage of body mass ranged from 56.5% in the non-athletic group to 65.1% in the body builders. Body builders scored higher than basketball players, distance runners and the non athletic group.

Starkey, et al., (1996) studied thirty-eight men to determine the effects of different volumes of high intensity resistance training on isometric torque and muscle thickness using one set (low volume, Ex-1, N = 18) or three sets (high volume; Ex -3, N = 20) for three times per week. Ten subjects acted as non training controls. Bilateral knee extension and flexion exercise was performed to fatigue within 8 to 12 repetitions for 14 weeks. The anterior, lateral and posterior right thigh, the medialis muscle and the lateralis muscle were assessed for the thickness by B - mode ultra sound. Both training groups improved torque output at most, but there was no difference between Ex - 1 and Ex - 3 increased muscle thickness at the medialis muscle, and 40% and 60% for the posterior right thigh. One set of high intensity resistance training
was as effective as three sets of resistance training in increasing knee extension and flexion isometric torque and muscle thickness in previously untrained adults.

Hickson, et al., (1980) conducted an exercise programme for nine men for five days a week for ten weeks to strengthen the quadriceps muscle. This study was undertaken to determine if heavy resistance training results in an increase in endurance, VO2max and whether the differences that were normally observed during bicycle and treadmill VO2max measurements in the same individuals were strength related. Following training, endurance time to exhaustion significantly increased while cycling (47%) and while running (12%) when the subjects exercised at 100% of their pre-training VO2max (4%) during bicycle exercise after training. Strength training had no significant effect on VO2max when measured during treadmill exercise. Absolute differences between bicycle and treadmill VO2max were essentially the same after training as before. Thigh girth increased significantly and muscle strength increased 40% with the training. These findings provide evidence that high resistance training was capable of dramatically increasing short term endurance, when the muscles involved in training were used almost exclusively during the testing without an accompanying increased in VO2max.
Wilmore, et al., (1978) studied the efficacy of a ten week programme of circuit weight training to elicit specific physiological alterations in 16 men and 12 women and another 10 men and 11 women serving as controls. The circuit consisted of 10 stations performed on an universal gym, three circuits per day (approximately 22.5 min/day), three days per week. The subjects exercised at 40-55% of 1 RM, executing as many repetitions as possible in 30 seconds on each of the lifts, followed by a 15 seconds rest as the subject moved to the next station.

Following the training programme, the experimental groups demonstrated significant increases in lean body weight, flexed biceps girth, treadmill endurance time, VE max (women only), V\textsubscript{o2} max in ml/kg min (women only), flexibility and strength. Significant decreases were found in selected skinfold measurements and in resting heart rate. No change was found in body weight or in relative or absolute body fat. The women exhibited equal or greater changes compared to men for all variables assessed. It was concluded that circuit weight training is a good general conditioning and attends to more than one component of fitness.

Mayhew, et al., (1993) conducted a study on anthropometric correlates with strength performance among resistance trained athletes. The results
indicated a high resistance relationship between estimates of regional muscle mass and lifting performance.

Weiss, et al., (2000) studied the effect of 21 sessions of squat training in 38 men with mean age of 21 years, in four groups. The group I, performed 4 sets of 3 to 5 repetitions, group II performed 4 sets of 13 to 15 repetitions and group III performed 4 sets of 23 to 25 repetitions. The control group did no formal physical training. Tests used to represent muscle size included body weight, thigh girth, net thigh girth and quadriceps femoris and hamstring thickness viz. B mode ultrasound. The results showed that, the thigh girth was greater in groups II and III than in control group; net thigh girth was greater in groups II and III than in control group, and quadriceps femoris thickness was greater in all 3 training groups than in control group. It was concluded that the observed muscle mass change following heavy resistance training was dependent upon both the training intervention and tool used for measurement.

Based on the available literature in the area of girth measurements, it is concluded that, the muscle mass and limb girths increased in body builders than the basketball players, distance runners and the nonathletes. (Spenst, et al., 1993). The high intensity resistance training of different intensities improved thigh muscle thickness in previously untrained adults (Starkey, et al., 1996). The circuit weight training programme significantly increased the
flexed biceps girth and lean body weight. (Wilmore, et al., 1978). The resistance training increased regional muscle mass and lifting performance (Mayhew, et al., 1993). The high resistance training was capable of dramatically increasing thigh girth, muscle strength and short-term endurance. (Hickson, et al., 1980). The bench press exercise performed by the college students altered the structural dimensions including upper arm and chest circumferences, upper and lower arm length, shoulder and hip widths percent of body fat and height. (Mayhew, et al., 1991).

HAEMATOLOGICAL VARIABLES

The knowledge of haematological and respiratory responses to exercise will help the strength and conditioning professional. The knowledge on this can be of particular value in developing the goals of a conditioning programme and can provide a basis for clinical evaluation and the selection of parameters.

Studies Related to Haemoglobin and Red Blood Cells

Various studies related to the haemoglobin and red blood cells are were reviewed below.

Dill, et al., (1974) found that the haemoglobin concentration was four percent lower in highly trained runners than the untrained, while David, (1984)
reported an increase in haemoglobin content of the blood in trained persons when compared to the untrained persons.

Schneider and Havens, (1980) reported that the physical exertion would increase the percent haemoglobin and erythrocyte content of the blood. Thomson, (1960) reported that the physical exertion increased the total erythrocyte count in the blood.

Digennaro, (1974) stated that the aerobic exercise not only increased the depth of breathing but also the volume of haemoglobin besides controlling blood pressure. Karpovich, (1955) observed a significant increase (10%) in red blood cells following short bout of physical exercise and the increase depended highly on the quality and duration of exercise. However the spurt of red blood cells subsided in a short time after the cessation of exercise.

Morehouse and Miller, (1976) observed an increase in red blood cells during the early stages of exercises and a decrease in level following prolonged exercise. Very strenuous exertion might also cause an increased rate of destruction of red blood cells due to compression of the capillaries. This was especially noticeable in persons with sedentary habits who rarely indulged in exercise.
Gore, et al., (1997) studied the correlation between relative haemoglobin mass (Hb mass, g x kg⁻¹) and relative maximal oxygen consumption $V_o_2$ max (ml⁻¹ kg⁻¹ min⁻¹) in 62 trained athletes (33 male runners, 12 male rowers and 17 female rowers) with national and international competitive experience. The correlation between haemoglobin mass and $V_o_2$ max was highest for the female rowers as ($r = 0.92$), lower for the male rowers ($r = 0.79$) and lowest for the male runners ($r = 0.48$). The results showed that the haemoglobin mass may be used to estimate potential aerobic power.

In a second series of experiments, haemoglobin mass was measured before and after three different training programmes in the same groups. The haemoglobin mass did not change following 12 weeks of intense rowing training, four weeks of heat training (32°C) or four weeks of medium altitude training (1740 m). These results showed that medium altitude training did not increase haemoglobin mass in trained athletes. Previous studies that have demonstrated increases in total red blood cell volume following altitude acclimatization used subjects with only modest aerobic power, whereas the present study used trained subjects. It was concluded that the trained athletes with erythrocythemic hypervolemia had limited capability to increase further either total red cell volume or haemoglobin mass.
Schmidt, et al., (1988) studied the effect of three weeks ergometer training five times a week for 45 minutes at 70% \( \text{V} \text{O}_2 \text{max} \) for six subjects on erythrocyte turnover and haemoglobin oxygen affinity. The reticulocytes increased from the second day after beginning ergometer training until a few days after its end, caused by an increased erythropoietin release by the kidney. Erythrocyte destruction was most pronounced in the first week and was markedly reduced in the third week of training.

Elevated glutamate oxaloacetate transaminase activity and creatine as well as lowered mean corpuscular haemoglobin indicated a younger erythrocyte population in the first week of recovery. Total blood volume increased during the course of training by 700 ml, mainly caused by a raised plasma volume (74%). Red cell volume increased later with maximal values one week after training. After training, all parameters of physical performance (\( \text{V} \text{O}_2 \text{max} \), maximal work load, heart rate during rest and exercise) were markedly improved, indicating fast adaptation mechanisms. The increased erythrocyte turnover, including higher erythropoiesis, seemed to be one important part of these effects.

Boyadjiev and Taralov, (2000) recorded the basic red blood cell variables in highly trained pubescent athletes of both the sexes from different sports and compared with those of the untrained group. Highly trained athletes
numbering 876 (559 boys and 317 girls) with mean age, weight and duration of training of 14.01 years, 56.24 kg and 3.52 years, respectively. The control group consisted of 357 untrained subjects (171 boys and 186 girls) with mean age and weight of 14.58 years and 57.75 kgs., respectively. The athletes were divided into seven subgroups as athletics (105), swimming (107), rowing (230), wrestling (225), weight lifting (47), various team sports (92) and other sports (67).

Venous blood samples were drawn from the cubital vein and the red blood cell count, packed cell volume, haemoglobin concentration and mean corpuscular volume were measured and statistically analysed by factorial analysis of variance to evaluate the statistical significance of the differences. The highly trained group had lower red blood cell count, packed cell volume and haemoglobin concentration than the control untrained group.

Dickson, et al., (1982) studied the haematologic parameters and serum ferritin levels in experienced ultra-marathon runners under control conditions, two days after a 160 km ultra marathon and for up to 14 days after a 56 km ultra marathon. Under resting conditions, 14 percent of the runners had subnormal serum ferritin levels compared to two percent of a control group. Serum ferritin levels that were markedly elevated after both ultra-marathon
races returned to pre-race levels only six days after the 56 km ultra marathon and continued to fall in athletes who did not exercise for a further eight days.

The haematologic changes include, immediate post-race haemoconcentration (shown by increased mean red cell count, hemoglobin level and packed cell volume) and increased mean corpuscular volume, followed by haemodilution that was greatest 48 hours after the 160 km race, an increased mean corpuscular haemoglobin concentration and reticulocyte production index; transient leukocytosis, monocytosis, lymphocytopenia, eosinophilia and the appearance of band cells. With the exception of the increased reticulocyte production index and the reduced packed cell volume, all other haematologic parameters had returned to control levels six days after the 56 km race.

Saltin, et al., (1986) studied the relationship of haemoglobin concentration of the blood and skeletal muscle capillarization in oxygen transport and uptake. The variation in arterial oxygen content due to different haemoglobin concentrations was compensated by the amount of oxygen delivered to the contracting muscle by a variation in blood flow. At the systemic level, with a large fraction of the muscle exercising, this caused an increase in submaximal heart rate and a lowering in maximal oxygen uptake in people with low, as compared to normal or high haemoglobin concentration.
The literature related to the haemoglobin and red blood cells concluded that there is an increase in haemoglobin content of the blood in trained persons than the untrained persons. (David, 1984; Schemider and Havens, 1980 and Digennaro, 1974). However, a lowered red blood cell count, packed cell volume and haemoglobin concentration was noticed in the highly trained group than the control group. (Boyadjiev and Taralov, 2000; Dill, et al., 1974). The resistance training has increased the red blood cell content of the blood (Thomason, 1960; Schmidt, et al., 1988; and Dicson, et al., 1982). A significant increase (10%) in red blood cells following short bout of physical exercise was noticed and the increase depended on the quality and duration of exercise (Karpovich, 1955).

**BIOCHEMICAL VARIABLES**

The biochemical parameters in the blood provide an insight into the intact of exercise in the system. Metabolic responses and training adaptations are largely regulated by exercise characteristics such as intensity, duration and recovery intervals. The biochemical tests are valid and reliable tests that one can accurately measure on individuals abilities.
Studies Related to Blood Glucose, Total Protein Albumin, Globulin, Blood Cholesterol, and Blood Lactate

The literatures related to the biochemical variables are reviewed below.

Blood Glucose

According to Dill, et al., (1935) increased physical activity caused fluctuations in the blood glucose level. Jourimae (1986) found that the exposure of athletes and untrained students to 20 kilometer running, had no effect on blood glucose.

Kristiansen, et al., (2000) subjected eight untrained subjects to endurance training with one thigh for three weeks using a knee-extensor ergometer. They were then subjected to two-legged glycogen depleting exercise and were given carbohydrate free meal thereafter to keep muscle glycogen concentration low. The next morning, dynamic knee extensions with both the thighs simultaneously at 60, 80 and until exhaustion at 100 per cent of each thigh peak workload was performed. Glucose uptake was similar in both thighs during exercise at 60 per cent of the thigh peak work load. At the end of 80 and 100 percent of peak work load, glucose uptake was on an average 33 and 22 percent higher, respectively, in trained compared with untrained muscle. Training increased the muscle content of glucose transporters (GLUT-
4) by 66 per cent. At exhaustion, glucose extraction correlated significantly with total muscle GLUT-4 protein. Thus, when working at a high load with low glycogen concentrations, muscle glucose uptake was significantly higher in trained than in untrained muscle. This may be due to the higher GLUT-4 protein concentration in trained muscle.

Tegeiman, et al., (1996) reported that the physical training affects carbohydrate metabolism and resulted in an increased insulin stimulated glucose disposal. The present study was conducted to investigate whether carbohydrate and lipid metabolism would be affected by nutritional factors in optimally trained elite ice-hockey players on two Swedish top-performance teams. Players on one team were subjected to extensive dietary monitoring and intervention, whereas players on the second team continued their ordinary diet. Blood levels of insulin, C-peptide, glucose, haemoglobin A1c, lipids and lipoproteins were measured repeatedly. Basal insulin levels and insulin resistance were significantly lower among athletes on both the teams compared with a sedentary group and muscle weight and body mass index were significantly higher. Exercise increases glucose utilisation by muscle, depending upon the mode, intensity and duration of the exercise. Exercise would also increase insulin sensitivity of the tissues, thereby increasing glucose uptake and utilisation.
Arieli, (1986) found an increased blood glucose value during the first hour and a decline thereafter in trained and untrained persons during an endurance exercise. In some studies, the mean blood glucose concentration remained elevated for at least 30 minutes following exercise (Van Ebben, 1996 and Singh, et al., 1997). In contrast, untrained subjects showed a mild increase in concentration of blood glucose following intense exercise.

Based on the literature available on the blood glucose, concluded that, the endurance training subjects, performing knees extensions with both the thighs, at the end of 80 and 100 percent peak work load showed higher glucose uptake in trained compared with untrained muscle (Kristiansen, et al., 2000). Resistance training increases glucose utilisation by muscle, depending upon the mode, intensity and duration of exercise (Tegeiman, et al., 1996). In the trained persons the blood glucose values were found to be increased and remain elevated for at least 30 minutes following exercise (Arieli, 1986; Van Ebben, 1996; and Singh, et al., 1997). Increased physical activity caused fluctuations in the blood glucose level (Dill, et al., 1935).

**Total Protein, Albumin and Globulin**

Elevated levels of total protein and albumin are found during dehydration. Decreased levels might be associated with a lack of proper diet or poor absorption of dietary constituent from intestinal tract. Excessive loss of
proteins resulting from burns, drawing wounds, renal disease may result in decreased level. Increased albumin are rarely seen except in the presence of acute dehydration and shock. Lowered serum albumin concentration was seen in starvation and malnutrition and in chronic gastro intestinal tract diseases and hepatic diseases. Decreases in concentration of individual globulin fractions may be encountered, but was seldom a decrease in total globulin concentration (Coles, 1980).

Walsh, et al., (1999) assessed the effect of an acute bout of high intensity intermittent exercise on saliva Ig A concentration and alpha-amylase activity in eight well-trained male games players. They reported to the laboratory after an overnight fast and performed a 60 minute cycle exercise task consisting of twenty one minute periods at 100% VO2max, each separated by two minute recovery at 30% VO2max unstimulated whole saliva was collected over a five minute period into pre weighed tubes and analysed for total protein, saliva Ig A and alpha-amylase. The performance of the intermittent exercise bout did not affect the saliva Ig A concentration, but caused a five fold increase in alpha-amylase activity and a three-fold increase in total protein concentration. These returned to pre-exercise values with in two to five hours post-exercise.
Yang, et al., (1998) studied the hepatic albumin synthesis rate in five volunteers with four men and one woman. The albumin hepatic fractional synthetic rate (FSR) and an absolute synthetic rate (ASR) were 6.39 ± 0.48% per day and 120 ± 9 mg. per kg body weight per day respectively after recovery from exercise. The FSR and ASR on the time control study were 5.94 ± 0.47% /day and 104 ± 9 mg.kg body weight per day, respectively. The six and 16 percent increases in FSR and ASR after exercise were associated with an elevated plasma albumin content at five and six hour of recovery, an increased total protein content throughout recovery and a negative free water clearance at two, three and six and half hour of recovery compared with base line values. These variables were unchanged from their baselines on the control study. Increased albumin content and reduced free water clearance contribute to a retention of fluid within the circulation after intense exercise.

Nagashima, et al., (2000) studied the albumin synthetic rates in seven healthy subjects at 1 to 5 and 21 to 22 hour after 72 minutes of intense (85% peak oxygen consumption rate) intermittent exercise and after five hour recovery in either upright or supine postures. Fractional synthetic rate of a albumin in upright postures increased significantly from 4.9 ± 0.9 % / day at control to 7.3 ± 0.9% / day at 22 hour of recovery. Absolute synthetic rate of albumin increased from 87.9 ± 17.0 to 141.1 ± 16.6 mg albumin.kg body wt (-1) day (-1). In contrast, fractional synthetic rate and absolute synthetic rate of albumin were unchanged in supine postures (3.9 ± 0.4 to 4.0 ± 1.4% / day and 74.2 ± 8.9 to 85.3 ± 23.9 mg albumin.kg body wt. (-1). day (-1) at control and 22 hour of recovery, respectively. Increased albumin synthesis after upright intense exercise contributes to the expansion of greater albumin content and its
maintenance. It was concluded that the stimuli related to posture were critical in modulating the drive for albumin synthesis after intense exercise.

Based on the literature available in the area of total protein, albumin and globulin, it is concluded that, the total protein and albumin were found to be elevated during exercise or dehydration (Coles, 1980). The fractional synthetic rate and absolute synthetic rate were increased and were associated with an elevated plasma albumin and total protein content during resistance training (Yang, et al., 1998). Increased albumin synthesis after upright intense exercise contributes to the expansion of greater albumin content (Nagashima, et al., 2000).

Blood Cholesterol

Hong and Lien, (1984) studied 11 men and five women athletes averaging 21 years of age, before and after four weeks of daily exhaustive exercise (six days a week) during an endurance training course. In comparing blood chemistries before and after training, concentrations of blood glucose, total serum lipids, serum triglycerides and serum cholesterol were significantly reduced; serum free fatty acid level was significantly increased and serum protein and serum phospholipid concentrations remained unchanged. It was concluded that exhaustive training produces reduced blood glucose but not clinically significant hypo glycemia with increased fat utilisation as a result of
depletion of carbohydrate storage. Such training reduces the resting levels of serum cholesterol and serum triglycerides.

Higuchi, et al., (1984) conducted a four week training programme for five healthy and mildly active males aged 28 to 31 years. They ran on a treadmill at 140 to 160 m/min at 0% grade for 50 min, five times a week, equivalent to an energy expenditure of 9 kg cal/kg body weight/day. They maintained their body weights by increasing calorie intake to match increased energy expenditure. No changes were observed in mean body weight, skinfold thickness, basal metabolism and maximal oxygen uptake after the training programme. However, the exercise training did not induce changes in plasma total cholesterol and triglyceride levels.

Lamon-Fava et al., (1989) studied the effect of an endurance triathlon (2.4 mile swim, 112-mile bicycle ride, 26.2 mile run in succession) on plasma total cholesterol, triglyceride, high density lipoprotein (HDL) cholesterol, low density lipoprotein (LDL) cholesterol, apolipoprotein (apo) A-I and B levels, and LDL particle size in 34 male and six female participants, six to twelve hours before and immediately after the completion of the triathlon.

A significant decrease was noticed in plasma triglyceride (70%) and plasma apo B levels in both men and women. A significant increase was noticed in HDL cholesterol in both men (18% increase) and women (5%
increase). Plasma triglyceride and LDL cholesterol did not change significantly in male athletes but decreased significantly in women. In men increase in HDL cholesterol was inversely correlated with the decrease in triglycerides significance. These results indicated that prolonged strenuous physical exercise can induce acute modification of plasma lipoproteins, which may in part be related to enhanced lipolysis.

Taralov, et al., (2000) found that the physical activity had a beneficial effect on the serum lipid profile in adolescent and mature human. For this study 876 highly trained athletes (559 boys and 317 girls) with their mean age, weight and duration of training, 14.01 years, 56.24 kg, and 3.52 years respectively were used. The control group consisted of 357 untrained subjects (171 boys and 186 girls) with mean age and weight 14.58 years and 57.75 kg, respectively. The athletes were divided into seven subgroups according to the sport practiced with 105 athletes, 107 swimmers, 233 rowers and 225 wrestlers, boxers and judos, 47 weight lifters, 92 from members of various team sports and 67 from other sports. Venous blood samples were drawn from the cubital vein and the concentrations of serum total cholesterol, HDL-cholesterol and triglycerides were measured.

The results of the study indicated that a) trained pubescents had lower serum total cholesterol than untrained boys and girls of the same age;
b) trained pubescent boys had lower serum total cholesterol than trained pubescent girls; c) the level of serum triglycerides was not relevant to the type of physical exercise in pubescence; d) long-term sport practicing was not able to decrease serum HDL - cholesterol levels in both sexes; e) sport affected serum total cholesterol to a greater degree than sex in pubescence.

Giada, et al., (1996) studied the lipoprotein profile, diet and body composition in twenty professional soccer players (mixed trained), twenty body builders (anaerobic trained) and twenty sedentary subjects, all males of similar age. No significant differences in total serum cholesterol, triglycerides, HDL - cholesterol, LDL - cholesterol, apolipoprotein A-I, A-II, B, C-II, C-III, and E levels were found among the groups studied. Bioelectrical impedance analysis disclosed significantly lower body fat percentages in both groups of athletes and increased fat free mass only in body builders. Daily calorie intake was higher and alcohol intake was lower in the athletes, compared with controls. Body builders had lower carbohydrate and higher protein and cholesterol intakes, while soccer players had a lower polyunsaturated to saturated fat ratio. None of the apolipoproteins examined was correlated with any body composition of diet parameters. No correlations between lipid parameters and anthropometric or dietary variables were found by multivariate analysis when the subjects were considered as a whole.
El-Sayed and Rattu, (1996) studied the effect of prolonged submaximal exercise followed by a self-paced maximal performance test on total cholesterol, triglycerides and high density lipoprotein cholesterol in nine trained athletes. Venous blood samples were obtained at rest, at 30 and 60 minutes during submaximal exercise and immediately after the performance test. Lactic acid, Hematocrit, Haemoglobin, total cholesterol and triglycerides were measured in the blood, while plasma was assayed for HDL-cholesterol. Plasma volume changes in response to exercise were calculated from hematocrit and haemoglobin values and all lipid measurements were corrected accordingly. In order to ascertain the repeatability of lipid responses to exercise, all subjects were re-tested under identical testing conditions and experimental protocols.

The data obtained during the two exercise trials were analysed by two-way ANOVA and no significant differences between tests were obtained. Consequently, the data was analysed by one-way ANOVA. Blood lactic acid increased nonsignificantly during the prolonged submaximal test, but rose markedly following the performance ride. Lipid variables ascertained at rest were within the normal range for healthy subjects. ANOVA showed that blood total cholesterol and triglycerides were unchanged, whereas HDL-cholesterol rose significantly in response to exercise. Post hoc analysis indicated that the latter change was due to a significant rise in HDL cholesterol after the performance ride. It was concluded that apparent favourable changes in lipid profile variables occur in response to prolonged submaximal exercise followed
by maximal effort and these changes showed a good level of agreement over the two testing occasions.

Giada, et al., (1995) examined 12 older and 12 young adult male cyclists first at the peak of their seasonal preparation and then again two months after its suspension. Sedentary males matched for age, weight and height comprised the respective control groups. During training, the body fat mass was significantly lower and maximum oxygen consumption (Vo2max) was higher in both groups of cyclists as compared with controls. No differences in serum total cholesterol, low density lipo protein cholesterol, apolipoprotein (apo) B, apo A-II, and fibrinogen were found. During the same phase, triglycerides and LDL-cholesterol to high density lipoprotein cholesterol ratio were significantly lower and apo A-1, HDL-cholestrol, HDL-3-cholesterol and the apo A1/apo B ratio were significantly higher in the athletes than their corresponding sedentary controls.

The studies related to the area of blood cholesterol concluded that, the exhaustive resistance training reduced the resting levels of serum cholesterol and serum triglycardes in both men and women (Hong and Lein, 1984). Strenuous physical exercises for a longer periods of time reduced the body fat, total cholesterol, triglycerides and plasma lipoproteins (Lamon-Fava, et al., 1989; Taralov, et al., 2000 and Giada, et al., 1996). The prolonged submaximal
exercise followed by a self-paced maximal performance test had favourable changes in lipid profile. The blood total cholesterol and triglycerides were unchanged but the HDL – cholesterol was significantly increased (El-Sayed and Rattu, 1996). Seasonal preparation in cyclists, reduced the body fat and triglycerides and LDL – Cholesterol to HDL – Cholesterol ratio were significantly lowered (Giada, et al., 1995).

**Blood Lactate**

Watson, (1985) has documented that the lactic acid produced by muscle would find its way into the blood stream and carried through out the body. The concentration could be easily estimated and often used as a measure of the energy produced from anaerobic glycolysis. The lactic acid content of blood continued to rise for a few minutes after the stoppage of exercise. Blood lactate concentration then slowly declined but remained elevated for approximately an hour.

Stanley, (1987) conducted a study on lactate kinetics in men at rest and during exercise and he concluded that lactate would turn over very rapidly in the blood at rest and during moderate intensity exercise. The circulating lactate was more important than glucose in providing oxidisable substrate during exercise.
Yoshida, et al., (1982) opined that the onset of blood lactate increase would differ according to the sites of blood sampling which should be considered for the interpretation of anaerobic threshold. The arteriovenous lactate difference became greater after the onset of increase in arterial blood lactate presumably as a consequence of lactate utilisation by the forearm muscle.

Poortmans, (1978) found that the non exercising muscles played a minor role in the removal of lactate during exercise and significant removal of lactate from the blood by non exercising muscles stopped soon after the cessation of exercise.

A study conducted by Thirumalaisamy, (1988) revealed that there was an overall significance in recovery lactate levels during mild exercise, sitting, standing and laying position.

Katz and Sahlin, (1988) reported that the lactic acid accumulates in contracting muscle and blood, beginning approximately at 50 to 70% of the maximal oxygen uptake, well before the aerobic capacity was fully utilized. The lactate production was increased to provide supplementary anaerobically derived energy. The present view was that lactate production during submaximal dynamic exercise was not oxygen dependant. Experiments in human and animal muscles under various conditions demonstrated that the
redox state of the muscle is reduced either before or in parallel with increases in muscle lactate. Based on the experimental data, it was concluded that lactate production during submaximal exercise was oxygen dependent. The amount of energy provided through the anaerobic processes during steady state submaximal exercise was, however, low and the role of lactate formation as an energy source was of minor importance.

Baker and King, (1991) studied the lactate removal rates in ten subjects during a 30 minute recovery period following an exhaustive arm exercise. Each subject experienced three recovery regimens on different occasions in random order. One recovery period consisted of supine rest, the second one incorporating low intensity arm exercise, the third one consisting of low intensity leg exercise. Lactate clearance rates showed a significant difference between the recovery regimens and a posterior test indicated a significant difference between leg exercise and arm exercise in the recovery period and also between leg exercise and rest. There was no significant difference in lactate clearance between arm exercise and rest in the recovery period.

Belcastro and Bonen, (1983) studied the lactic acid removal rates during recovery, at rest and exercises at 29.7, 45.3, 61.8 and 80.8% \( \text{Vo}_{2\text{max}} \) after a standardized six minute bicycle ergometer exercise, and twice while the seven subjects regulated their own recovery exercise. Blood samples were taken after the standardized exercise at every fifth minute during the 30 minutes recovery period. During the controlled recovery periods, lactic acid removal rates were dependent on the intensity of recovery. Optimal removal
was predicted to occur at 32% \( \text{Vo}_2 \text{max} \). Removal rates during the self regulated recoveries were not different, but these removal rates were faster than during recovery at rest and exercise at 61.8 and 80.8% \( \text{Vo}_2 \text{max} \). Removal rates during the self regulated recovery and recovery at 29.7 and 45.3% \( \text{Vo}_2 \text{max} \) were not different. The subjects were therefore able to remove lactic acid effectively when selecting their own recovery exercise.

The literature available in the area of blood lactate, on analysis concluded that, during the moderate intensity exercise the blood lactate turn over was very rapid and the circulating lactate was more important than glucose in providing oxidizable substrates during exercise (Watson, 1985; and Stanley, 1987). The non exercising muscles played a minor role in the removal of lactate during exercise and it stopped soon after the cessation of exercise (Poortmans, et al., 1978) During mild exercise, sitting, standing and lying position there was an overall significance in recovery of lactate levels. (Thirumalaisamy, 1988). The amount of energy provided through the anaerobic processes during steady state submaximal exercise was low and the role of lactate formation as an energy source was a minor importance. (Katz and Sahlin, 1988).