CHAPTER II

REVIEW OF RELATED LITERATURE

Man is the only animal that does not have to begin new in every federate generation, but can take advantage of knowledge, which has been accumulated through the centuries. Unlike other animals, man builds upon the accumulated and recorded knowledge of the past.

The review of related literature, concerning any topic under investigation should be exhaustively and extensively conducted for clear understanding of the area under study, methods used to collect the data and to determine the statistical techniques to be used. Thus, the review of the related literature helps to avoid the risk of duplication and provides insight and ideas for further investigation in the specific area of study. (Thomas and Nelson, 1991)

Therefore, a systematic, exhaustive and scholarly attempt was made by the investigator to scan through the current literature, from the available books, monographs, journals, thesis, internet and also by computer literature search. A brief review of the studies related to the present topic is presented below.
The review of literature collected has been presented under five major sub-sections as detailed below.

a. Physical fitness components and performance
b. Physiological aspects and performance
c. Anthropometrical aspects and performance
d. Biochemical aspects and performance and
e. Hematological aspects and performance

2.1 Physical Fitness Components and Performance

Important physical fitness components such as speed, agility, flexibility, cardiovascular endurance and motor ability are essential for success in sports and games. The above factors are specific to different sports and games. The physical factors such as height and weight are advantageous in certain sports and games. In this subsection the physical fitness studies are reviewed.

Hassain (1989) conducted a study to determine relationship of selected physical fitness variables (speed, power, cardiovascular endurance and agility) to performance in basketball. Twenty five basketball players from the professional college of physical education were selected as subjects. They were administered the AAPHER physical fitness test to collect the data.
pertaining to the selected physical fitness variables. The result of the study revealed that agility, cardiovascular endurance and power were significant to performance in basketball with an obtained 'r' value of 0.7, 0.55 and 0.52, for power, endurance and agility, respectively whereas speed did not show significant relationship (r = 0.08).

Mishra (1983) studied the relationship of selected physical and physiological variables in 50 meter front crawl swimming performance. The subjects were 25 professional male students of physical education studying in LNCPE Gwalior. Data was collected on arm length (Roger’s Physical Fitness Index) ankle flexibility (goniometer) vital capacity (spirometer) and body surface area (Bunn Bois) and the performance was recorded in seconds. Pearson Product Moment correlation was computed to assess the relationship of physical and physiological variables to speed on fifty meter swimming. It was concluded that: there was no significant positive relationship between arm strength ankle flexibility and vital capacity to swimming speed and there was no significant relationship between body surface area and swimming speed.

Jenner (1971) conducted a study on agility with hundred students who were divided into two equal groups as athletes and non athletes. To measure agility twenty five tests were used. The findings indicated that performance on agility tests were accounted for fast reaction time, speed of movement,
strength, balance, change of position or change of direction, body size and form. A significant difference was found between the mean factor scores for various group of athletes.

Gutin, Gogile and Kerry (1976) determined the relationship between directly measured aerobic power and a variety of fields tests including runs of 12 min 600, 1200 and 1800 yards. Aerobic power was also predicted from submaximal heart rate while cycling using a modified Astrand Rhyming procedure. This study showed that in children training reduced submaximal heart rate without effecting maximal oxygen uptake implying that maximal oxygen uptake and submaximal heart rate are related. Therefore the relationship between submaximal heart rate and running performance were also high.

Hirata (1966) studied in 1960 Olympic throwers and found that they were heavier and taller, with muscular arms and wider shoulders when compared to other athletes.

Ritchson (1968) studied 100, fourth grade boys and girls and correlated age, height, weight, leg length, body movement time, 50 yard dash, shuttle run and standing broad jump. The main scores on AAPHER test items were compared to national norms. Several significant correlations were found with height and weight with leg strength and leg length with 50 yard dash.
Gallagher (1964) investigated the relationship of agility to performance in women's inter collegiate basketball. The hypothesis that high positive relationship would exist between items of the test (McCauliff Agility components test) and performance were not supported. The lack of evidence to support the hypothesis was attributed to some unexpected peculiarities of the sample.

Anusa (1979) conducted a study, with 46 subjects well conditioned soccer players having two years playing experience at the college level. They were tested for running speed, power, agility, maximum oxygen consumption, strength, anaerobic capacity and flexibility. In addition, 11 anthropometric measurements consisting of skinfolds and diameters were taken. Soccer playing ability served as the criterion and was measured by the rankings of three experienced soccer coaches based on selected soccer skills and strategies. Analysis of data was by zero order correlation and multiple R analysis resulted in the following conclusions; age (experience) is the best single predictor of playing ability, VO$_2$max and running speed are considered important factors in soccer performance. Flexibility, agility, lactate concentration and leg power are not considered as valid indications of playing ability.

Medued (1966) studied the height and weight of sportsmen and women. The greatest deviations regarding heights in the positive sense were
observed in basketball players and volleyball players and swimmers. Whereas wrestlers, boxers and figure skaters were among the sportsmen showing deviations in height in the negative sense.

Childress (1972) in his study determined the effectiveness of selected physical variables in predicting a basketball performance through a factor and discriminative analysis. The test items were selected through review of the related literature as valid measures of the components of height school playing ability. The test items were administered to 106 high school basketball players and the resultant data were analyzed through factor analysis. Six factors were identified were agility, speed, relative muscular strength, total body movement time and manual dexterity. Two test batteries were constructed. The first consisting of six test items, the second was composed of ten test items. The results of this study indicated that the components of basketball ability could be isolated, measured and utilized to construct an evaluation tool for classifying players into two populations identified as successful and unsuccessful.

Abdo (1966) conducted a study on leg length, height and weight factors in relation to cardiovascular efficiency of college women. Chest width and pelvic width were also among the factors studied data collected from 193 subjects, were inter related. The results indicated that excess weight had effect
on cardiovascular efficiency while leg strength correlated positively with step test performance. The linear correlation between cardiovascular efficiency and Ponderal index was significant but the regression line levelled off for women with high cardiovascular efficiency.

Singh (1978) conducted a study in order to evaluate the physical fitness of hockey players. A sample of 67 randomly selected male hockey players acted as subjects from the total hockey playing population of Punjab, India. The subjects were tested in the Fisherman's basic physical fitness test, which included extend flexibility, dynamic flexibility, explosive strength, static strength, dynamic strength, trunk strength, co-ordination, equilibrium and endurance. The data were statistically analysed by computing mean, range and standard deviation.

The scores of the subjects in hand grip, softball throw, shuttle run and 600 yard run and walk test were much more than in other tests indicating higher levels of explosive strength and static strength of arms, cardiorespiratory endurance and leg explosive strength.

The research studies in physical fitness and performances have documented that agility, cardiovascular endurance and power are significant factors required for peak performance in basketball (Hassain, 1989); agility, VO₂max and running speed are considered as important contributing factors in
soccer performance (Anusa, 1979) and Medued (1966) has documented that height and weight of sportsmen and sportswomen are important physical factors for volleyball and basketball players.

2.2 Physiological Aspects and Performance

Physical activity and training brings about specific metabolic and physiological changes in untrained and trained athletes. The important physiological changes that occur in individuals due to acute exercise and chronic training are reviewed below.

Katch, Freedson and Stausody (1976) investigated the difference in actual and predicted vital capacity and residual lung volume in sixty three male subjects who were classified as either large, medium or small using a sizing technique based on weight and height criterion. Vital capacity and residual volume were significantly different (P<0.05) between the three different groupings of subjects (small, medium, large) when attempting to predict vital capacity of residual volume from height, weight density, lean body mass, percent fat, chest girth and age. The standard errors of prediction ranged 9 to 11 percent for vital capacity and +17 to 19 percent residual volume.

Tatarinov (1965) points out that systematic physical training and sports favour an increase in the vital capacity of the individuals. He adds that the
vital capacity of the individuals in female is lower than male and it is higher in young people as compared with old people.

Uppal and Tudian (1984) studied the comparative effects of different frequencies of endurance training of cardio respiratory endurance. According to their findings, the cardio respiratory endurance of secondary school students can be effectively improved by administrating a progressive programme of interval training with, varied frequencies of training, with twice, thrice and five sessions per week training. Endurance training works out with interval training method, administered twice, thrice and five days a week develops cardiorespiratory endurance and workouts five times a week more effective in developing cardio respiratory endurance as compared to workouts twice and thrice a week.

Bird and Hay (1987) observed variations in heart rate with pre exercises food. Students were studied during multistage cycle ergometer tests. The tests were repeated on 5 occasions following the ingestion of different pre exercise meals and the results were compared. A glucose adoption taken three hours prior to the exercise resulted in the lowest heart rates at each work rate. The highest heart rate at each work were recorded following the ingestion of glucose one hour before exercise.
Santo and Frankdel (1976) conducted a study to find the effects of physical conditioning programmes on selected physiological components of college men. The subjects were 76 men from a junior college. They were divided into four different physical conditioning programmes, one was a control group which had no formal conditioning programme. The interval conditioning, aerobic conditioning and physical education conditioning groups showed significant increase in cardiovascular efficiency compared to control group.

Yoest (1975) in his study made an experiment on 57 boys of junior high school and 43 college males from physical education classes to find out the relationship between cardiovascular fitness and selected body measurements. The measurements determined on each group were age, height, weight, skinfold triceps, body density, percent body fat, lean body mass and the body surface area. The Ohio State University step test was administered to both groups. Pearson correlation was used to determine the relationship of body measurements to step test performance. The finding indicate that the subjects adolescent or adult who possess larger percentage of lean body mass registered higher score on the step test.

Coyle and Himmest (1986) in their study investigated the effect of detraining on cardiovascular responses to exercise and role of blood volume.
In this study they had determined whether the decline in exercise stroke volume observed when endurance trained men stop training for a few weeks associated with a reduced blood volume. In addition to it, they determined to extent to which cardiovascular function could be restored in detrained individuals by increasing blood volume to similar level as during training. They found that the decline in cardiovascular function following a few weeks of detraining is largely due to reduction in blood volume, which appears to limit ventricular filling during upright exercise.

Santo (1977) selected 76 college men to study the effect of regular physical education programme. Cardiorespiratory fitness was measured using the Harvard Step Test and 12 minutes run test and three minutes shuttle run. It was concluded that regular physical education programme group improved significantly in cardiorespiratory fitness when compared to control group.

Davis (1973) in his study selected 1189 university students to study the effects of three different intensive training programme on cardiorespiratory fitness. The subjects were assigned to one of three experimental or control group. The methods of training employed were rest load training procedure, continuous running and high intensity running. The subjects followed prescribed work out percentage for 30 min per session and trained for three sessions in a week. It was concluded that three training groups showed
significantly greater improvement in cardiorespiratory fitness than did the control groups.

Padmavathi and Gupta (1959) and other conducted a study on blood pressure of low and high income groups in Delhi, variation of blood pressure with age and weight determined. With the low income group there was a little rise in blood pressure with the age except with increase in body weight. In the high income group the body weight and blood pressure were higher in every age decade than in the low income group. There was a consistent rise in blood pressure with age and weight. The low income group had lower systolic blood pressure than high income group, where diastolic blood pressure was lower after age 40. The increase in blood pressure over 140/90 was low among all classes in India. The lower body weight appeared to be the important factor to control blood pressure.

Pierce, Rosenek and Stone (1993) investigated the response of lactate (La) heart rate (HR) and rate of perceived exertion (RPE) to acute resistance exercise following a high volume weight training programme. Twenty three untrained male subjects were divided experimental and control group. A pretest was performed and following eight weeks of training all subjects were retested. Results showed that peak La decreased as a result of training. The experimental group subjects displayed a significant reduction in heart rate at
the end of each set. Significant decreases in RPE during training were also observed. These findings suggested that eight week high volume weight training programming emphasizing large muscle groups can reduce the physiological and perceived stress associated with resistance exercise.

Vaccaro, Clarke and Wrena (1979) conducted a study on physiological profiles of elite women basketball players. In this study 15 members of the University of Maryland Women’s basketball team were selected. The results of the analysis suggest that means for height and weight were greater than those of the average female and most other women athletes. Mean percentage of fat was less for female non-athletes but somatotype was similar to normal young women.

Alteri (1975) selected 63 college females between 17 and 22 years of age to study the effects of endurance and interval running on selected physiological parameters. Resting pulse rate was one of the physiological parameters selected. Analysis of data revealed that both treatments resulted significantly lowered resting pulse rate.

Bale and Davis (1978) investigated body build explosive strength, grip strength and cardio respiratory fitness of a group of 43 top class female field hockey players and sports women. The hockey players were divided into four groups according to their respective playing positions on the field and the
morphological strength and fitness variables were examined in relation to their field positions. The somatotype and body composition of the forwards and half back were similar but both these groups were lighter had lower percent fat and lean body weight than the backs and goal keeper. The half backs were fitter both in the tests of explosives strength and in the test cardiovascular fitness.

The research studies reviewed under the subsection physiological aspects and performance documented above, revealed that vital capacity and residual volume were different based on body size of athletes (Katch, Freedson and Stausody, 1976); there in increase in cardiovascular fitness (Davis, 1973, and Coyle and Himmest, 1986) and reduction in resting heart rate due to interval and endurance training (Pierce, Rosenek and Stone, 1993).

2.3 Anthropometrical Aspects and Performance

If the body segments can be moved at the same angular speeds those with longer limbs will have greater linear velocities. Some authors have suggested that the distance of the muscular attachment from the joint will differ in individuals. The greater the distance, the longer the effort arm (Cooper and Glasscow, 1972).
The longer the power arm of the lever, the greater the amount of force, the shorter the power arm in relation to the length of the weight arm, the smaller is the moment of force but the more immediate is the action (Bunn, 1972). Anthropometric assessment provides information about athletes and the unique physical characteristics required for a specific sport.

Kim et al. (2002) collected data on 236 males and 191 females from the ages 6, 9, 13, and 15 years residing in rural areas and 237 males and 219 female of the same ages from the families of rural to urban migrants in South Korea. Comparisons were made between urban and rural groups for measures of body size and form, skinfold thickness, the body mass index (BMI), and estimated arm muscle area (ARM). There was a significant main effect for urban-rural differences in arm girth, upper limb index, and ARM. Rural males were larger in these variables. Among females, only arm girth was significantly different. Age at menarche was significantly earlier in the urban sample (12.6 years) than in the rural sample (13.0 years). Compared with both recent and earlier data for South Korea, present-day 6-, 9-, 13-, and 15-year-old males and females are taller and heavier at every age, indicating secular gains.

Guidetti, et al. (2002) studied the relationship of the middleweight class, the relationship between ranking in boxing competition performance and
some physiological factors. The athletes were ranked following the criteria of World Amateur Italian Boxers Association ranking. Anthropometric measurements, such as body fat percentage, upper arm and forearm muscle cross sectional areas were estimated along with tests of grip strength, maximal oxygen uptake, blood lactate, individual anaerobic and ventilatory threshold. The results suggest two basic factors were related highly with boxing competition ranking, namely, the VO\textsubscript{2} at individual anaerobic threshold and the hand grip strength.

Backe (1964) conducted a study by relating selected anthropometric measures with hop step and jumps. Eighty seven secondary school boys acted as subjects in this study. There was significant relationship between body height, leg length and performance in hop step and jump event was obtained. Similarly significant relationship was found between anthropometric measurement with height, leg length, body weight and physical performance measures like speed, strength and distance covered in running and broad jump for boys as reported in some other studies.

Weiss, et al. (2000) compared several indices that might be used to depict muscle size. Four groups of men were exposed in heavy resistance training designed to elicit differential hypertrophic adaptations following 21 sessions of squat training. Tests used to represent muscle size included body
weight, thigh girth, net thigh girth, and quadriceps femoris and hamstring thicknesses via B-mode ultrasound. It was observed that muscle mass change following heavy-resistance training is dependent upon both the training intervention and tool used for measurement.

Roemmich and Sinning (1996) studied the changes in body composition, somatic growth, power and strength of high school wrestlers and controls. The subjects selected were studied during the early, middle, late, and 3.5-months post-season. Elbow flexion peak power, peak torque, extension peak power, and peak torque were measured on an isokinetic dynamometer. Compared to controls the wrestlers had a significant increase in mid arm girth and flexed mid arm cross sectional muscle area during the wrestling season and larger increases in shoulder girth, mid arm girth and anterior posterior chest breadths during the post season. It was found that wrestlers demonstrated a lack of lean tissue accretion and reductions in strength. At post-season these variables returned to, or were above, pre-season levels. Results of analysis of covariance indicated that lean tissue changes were associated with the changes in strength and power.

Spenset, et al. (1993) determined limb girths and skinfold thicknesses in 62 male athletes and 13 non-athletic males. The muscle mass means ranged from 38.4 kg for the distance runners to 58.7 kg for the body-builders. Both
Body-builders and basketball players had significantly greater muscle mass than gymnasts, long sprinters, non-athletic males and distance runners. The muscle mass was greater in track and field power athletes than in distance runners.

Musaiger, et al. (1994) conducted a study on body composition with a sample of 304 athletes selected from first class clubs in four common sports, namely, football, handball, volleyball and basketball and compared with 53 non-athlete adults. Weight, height, mid-arm circumference and skinfold thickness were measured and it was found that there were differences in body composition among athletes according to the type of sport. Basketballers and volleyballers were the tallest athletes, while handballers were the heaviest. The skinfold thickness measurements showed that basketball and handball players have more subcutaneous fat than other athletic groups. As compared with non-athletes, the Bahraini players had higher means for height, weight, subscapular, suprailliac thickness and mid-arm circumference.

Marrow (1979) obtained various anthropometric, strength and speed variables on 180 inter collegiate women volleyball players and related them to team success. Factors analysis of the measured variables showed that the variables could be dimensioned as body size, speed and the strength. Multiple discriminate analysis showed that the team were significantly different on the
factors of strength and speed. Team centroids were plotted in two dimensional discriminate space and the graphic representation showed that the stronger, faster, leaner teams were the most successful in tournament play. Multiple discriminant analysis identified upper body strength and fat weight as most important in differentiating between players of the most and least successful teams.

Body build and performance characteristics were studied by Hollings and Robson (1991) in 38 elite young male track and field athletes. The athletes were divided into four groups depending on the event namely, sprinters/hurdlers, jumpers, throwers and middle distance runners. Performance characteristics determined were vertical jump, the Margaria stair run and the Wingate Test. Analysis of variance showed that the throwers were significantly different from other groups in body build and middle distance runners were significantly different from other groups in performance characteristics. Further investigation revealed that among the four groups studied, body weight and vertical jump for height are two simple measures of differentiating between event participation.

Fleck (1983) conducted a study on 528 male athletes participating in 26 Olympic events and 298 female athletes participating in 15 Olympic events and assessed percent body fat and lean body mass via hydrostatic weighing
and/or anthropometric methods. All groups of athletes were below the average values for percent fat of college age men and women of 15% and 25%, respectively. In general, athletes involved in a sport where their body weight is supported, such as canoe and kayak and swimming, tended to have higher percent fat values. Athletes involved in sports where a weight class has to be made to compete, such as boxing and wrestling, events such as the 100, 200, and 400 meters in athletes that are very anaerobic in nature and extremely aerobic events such as the marathon demonstrated lower percent fat values. Athletes involved in sports where body size is a definite advantage, such as basketball and volleyball tended to have a larger lean body mass.

Karakomer (1964) in his study attempted to determine the relationship between anthropometric measure and performance in running high jump. The results of this study showed little influence of the skeletal measures on the height of the jump. However a combination of height, leg length and breadth of foot was found to be significantly related to performance in high jump.

Stuart and Collins (1968) selected twenty athletes on various university team engaged in competition and twenty athletes (no regular exercise or manual labour for 20 years) were paid as to age height weight and body surface area tested for vital capacity and maximum breathing capacity
results showed that the athletes had a significantly higher vital capacity than the non athletes.

Rasch (1968) studied the relationship of arm length, weight, length to speed arm movement. In this study, the length, strength and weight of the arm and its segments are measured and correlated with the maximum speed of voluntary movement. From the experimental findings recorded there is no satisfactory significant relationship between the speed of voluntary movement of the hand fore arm and the weight, length and strength of the arm and its segments.

Alexander (1973) designed this study to investigate the relationship between the somatotype rating and other selected anthropometric measures and the Basketball players. The subject were the 53 participating in the 1974 Canadian women inter collegiate athletic union basketball Championship performance was evaluated during the six games of the championships. The result indicated that none of the basketball performance measures was significantly related to any of the health related somatotype component. However, total basketball performance points scored and rebounding were related to the height of basketball players. Tall players were generally more highly skilled. The top ten players were identified on the basis of following
anthropometric measures viz., humerus diameter, biceps girth, calf, girth, height and weight.

Pisque (1962) compared skinfolds and other anthropometric measurements of 647 Italian, Jewish and Negro pre adolescent boys from Boston, Massachusetts and skinfolds were measured at three sites. Other measurements included height, weight, biilliac diameter and selected girth measurements. The largest percentile scores were found in the Jewish group. Analysis of variance was employed to compare the body fat, height and weight of each group showed significant difference between ethnic groups at the one percent level.

Lundergan (1960) conducted a study on changes in skinfolds and girth measurements of women varsity basketball and field hockey players. The pre and post season subcutaneous fat, girth and weight measures were investigated on women varsity field hockey players and varsity basketball players at Pennsylvania State University. Results of comparison of pre and post mean scores indicated that the field hockey players showed a decrease in fat at the arm with a reduction in girth at arm, iliac and umbilical site with a reduction in girth of the thighs.

Salkum and Mathur (1985) measured that anthropometric measurements and body composition of the 150 female athletes.
Nonsignificant differences were observed between the anthropometric variables and body composition of university and national level athletes. The measurements were significantly different between athletes and non athletes and between the athletes and different sports (volleyball, basketball, throwers, sprinters and distance runners). Difference in various measurements within the athletic group have been attributed to physical demand of each sport.

Clarena (1969) studied the factors associated with success in volleyball of 28 women university players during intramural tournaments at Illinois State University. Two experienced volleyball coaches judged each player by observing the game and the score taken as a criterion variable. The following variables were also measured, namely, height, weight, leg extension, strength using adjustable dynamometer, skinfolds, the large caliper, jumping ability by using jump and reach test and apparatus constructed by the investigator to measure the reaction and movement time. Through the test and correlations it was found that jumping ability and reaction time were significantly related to successful volleyball playing ability. A multiple correlation R of 0.718 was obtained from the criterion variable and the other nine variables. An r of 0.53 was obtained from the criterion and reaction time and jumping ability (0.52). The regression equation computed in this study could be used to predict success in volleyball playing alone.
Shondell (1972) investigated selected physical and anthropometric variables of successful collegiate volleyball players. Coaches were interviewed and literature were reviewed to determine physical characteristics of volleyball players. An initial group of 23 subjects were selected to measure the characteristics of successful players. A jury of the four judges served to provide the criterion based on overall volleyball performance. Ninety three subjects completed all 123 items. Statistical techniques utilized provided intercorrelation coefficient variables, stepwise regression coefficient and constants and the square of the multiple correlation coefficient for the regression equation at each step. It was concluded that power appeared to be most significant factor for successful volleyball performance and six items battery as invalid predictor of volleyball performance.

Torida, Adeniran and Ogunieni (1987) conducted a comparative study of the body composition and anthropometric characteristics of elite male basketball and volleyball players and male non athletes. The ages of the subjects ranged from 19 to 29 years. The basketball players were significantly taller and had markedly larger humerus width than the volleyball and the non athlete groups. The non athletes had significant higher percentage of body fat values than both the groups of athletes. The basketball and volleyball players
were predominantly ectomesomorphic than the ectoendomorphic non athletic group.

Yoest (1973) conducted a study on the relationship between cardiovascular fitness and skeletal anthropometric measurements. Fifty one eighth grade boys and 43 college male subjects were selected from each group. A cardiovascular test was administered to both age group to determine cardiovascular fitness. The Ohio State University test was administered to the college men and modified version of the same was used for the younger subjects. Pearson’s Product Moment correlations were used to determine the relationship of the body measurements to the performance of step test. The factors of age, height, lean mass and body surface are did not significantly limit step test performance. The factors of body compositions were principal indicators of permit body significantly limited the college men’s step test performance but not that of the 13 to 15 years old boys. The study suggested that the subjects, adolescent or adults, who possessed large percentage of lean body tissue registered higher scores on the step test.

In the study of Sodhi (1974) anthropometric measurements height, weight and siting height were taken for 57 hockey players of five upper level teams of Punjab University, Patiala, who participated in Intercollegiate competition of the university. The data were divided into four groups The
goal keepers, backs halves and forwards according to their special positions in the field. The results indicate that all the measurements decline gradually from keepers forwards to the back ward line players. The former being heaviest and tallest as compared to the later. The substantial height variations were also found between the positions of the players.

De, et al. (1991) examined forty athletes of South Asian Federation (SAF) Games participating in short distance, long distance and marathon jumping and throwing events. The athletes were short distance, long distance and marathon runners, jumpers and throwers who were persuaded for the purpose. The throwers and the jumpers comprised the oldest and youngest group of athletes, respectively. The throwers were observed to be the tallest and heaviest, whereas the long distance runners were of short height and lightweight. The highest mean values of Peak Expiratory Flow Rate (PEFR) (lit/min) were noted among the throwers followed by marathon and long distance runners. The lower values of PEFR were noted among the short distance runners and jumpers. The PEFR values, when arranged according to height, were noted to be insignificant increasing with the increase in age. The overall values of height, weight and PEFR were all found to be higher in these elite sportsmen when compared with their non-sportsman Indian counterparts.
Bale, et al. (1985) investigated female marathon runners of varying standards on how they differed in body composition and physique and in their training regimes, and developed predictors of distance running performance from the anthropometric and training variables. Female marathon runners were divided into three groups according to their best time for the 26.2 mile race. The subjects were assessed for body composition and somatotype using anthropometric techniques and completed a questionnaire about their current training for the marathon. No difference was found between the groups in height, bone widths and circumferences and had similar body weights of approximately 53 kg, a value which is much lower than the average for sedentary women. While all the runners had a lower percent fat, as measured from skinfold thicknesses than the sedentary women, the elite runners were seen to have significantly lower values than the other two groups. The difference in body fat was particularly reflected in the triceps skinfold value. Multiple regression indicated that the number of training sessions per week and the number of years training were the best predictors of competitive performance for both 10 mile and marathon distances. They also indicated that female long distance runners with a slim physique and high in ectomorphy had the greatest potential for success.
Research studies documented above on anthropometric aspects and performance of different players revealed top players in basketball and volleyball had higher height and weight in anthropometric measures when compared to other major games (Alexander, 1970; Spenset, et al., 1993 and Musaiger, et al., 1991).

2.4 Biochemical Aspects and Performance

The physiological adaptations to training results in the athletes participation in further exercise or training sessions with less severe homeostatic disturbances than in untrained state. The important biochemical variables, namely, blood glucose and cholesterol are reviewed below.

Dunstan, et al. (1998) in their study assessed the effects of short-term circuit weight training on glycaemic control. Twenty one subjects performed regular self-blood glucose monitoring throughout. Fasting serum glucose and insulin were measured following a 12 hour fast and during an oral glucose tolerance test (75 g) before and after 8 weeks. It is found after adjustment for body mass changes, the change in self-monitored glucose levels and insulin area under the curve, but the glucose area under the curve remained significant.

Ivy (1997) made a comprehensive study on glucose tolerance and non insulin dependent diabetes mellitus subjects. Moreover, it was found that the
protective effect of physical activity was strongest for individuals at highest risk of developing non insulin dependent diabetes mellitus. Exercise training results in preferential loss of fat from the central regions of the body and should therefore contribute significantly in preventing or alleviating insulin resistance due to its development. Likewise, exercise training can prevent muscle atrophy and stimulate muscle development. Muscle glucose uptake is equal to the product of the arteriovenous glucose difference and the rate of glucose delivery or muscle blood flow. While it has been known for many years that insulin will accelerate blood glucose extraction by insulin-sensitive peripheral tissues, recent evidence suggests that it can also increase glucose extraction by insulin-sensitive peripheral tissues. Recent evidence suggests that it can also acutely vasodilate skeletal muscle and increase muscle blood flow in a dose-dependent manner. Evidence has been provided that morphological changes in muscle, particularly the capillary density of the muscle, are associated with changes in fasting insulin levels and glucose tolerance.

The effects of intermittent liquid meal feeding on selected hormones and substrates during intense weight training was studied by Fahey et.al. (1993). Ten male subjects were given a meal or nonnutritive placebo before and intermittently during a two hour weight training session, and a meal before
and intermittently during 2 hours of rest. Serum insulin increased from $12.2 \pm 1.2$ and $11.2 \pm 1.3$ before feeding to $37.2 \pm 4.8$ and $45.0 \pm 5.0$ mU.ml$^{-1}$ during exercise in meal and non nutritive placebo groups, respectively, and remained elevated for 120 min. Insulin remained at resting levels throughout the experiment. Glucagon remained unchanged in all groups. Thus it was found feeding a liquid meal before and during weight training exercise can increase serum insulin and maintain blood glucose for a prolonged period.

The need for early emphasis in diet and exercise was constructed by Barnard, Jing and Inkeles (1994). The aim of the study was to investigate the effectiveness of an intensive diet and exercise programme for controlling noninsulin dependent diabetes mellitus and reducing risk factors associated with macro vascular complications. It was found that life style modification consisting of diet combined with aerobic exercise can be effective for controlling noninsulin dependent diabetes mellitus and reducing risk factors associated with macro vascular complications in both men and women.

Roef, et al. (2002) studied the role of lactate in gluconeogenesis during exercise in untrained fasting humans. They concluded that lactate infusion during low-intensity exercise in fasting humans (1) increased gluconeogenesis from lactate, and (2) increased glucose production, thus increasing the blood glucose concentration. These results indicate that gluconeogenesis capacity is
available in humans after an overnight fast and can be used to sustain blood

glucose levels during low intensity exercise when lactate, a known precursor of
gluconeogenesis, is available at elevated plasma levels.

Haluzikova, et al. (2000) made a study to follow the influence of the

regular hard physical training on the serum leptin levels. Therefore, the serum

leptin levels in top rugby players, top race walkers and age and gender

matched control group were compared. The relationship between serum leptin

concentrations and body mass index and body fat content was also studied. It

was found that serum leptin levels in rugby players were significantly higher

than in race walkers group, but lower than in control one. Serum leptin levels

in race walkers group, but lower than in control one. Serum leptin levels in

race walkers were lower than those of rugby players and of control group. The

body fat content in race walkers was lower than resting two groups. There was

no significant difference in body fat content between control and rugby players

group. Serum leptin levels correlated positively with body mass index and

body fat content both in control and in rugby players group. No statistically

significant relationship was found between leptin and body mass index or body

fat content respectively in race walkers group. It was concluded that serum

leptin levels in top sportsmen are lower than in non-sporting healthy age and

gender matched controls. The lower leptin levels in top sportsmen are
probably in part the result of lower body fat content and in part the result of complex neurohormonal adaptation on the long term physical training.

Haluzik, et al. (1998) compared the body weight, the body mass index, the body fat content as measured by caliper as skinfold thickness and the serum concentration of leptin, triglycerides, total, high density and low density lipoprotein cholesterol in 14 top rugby players and 10 healthy controls. It was found that serum leptin, total and low density lipoprotein cholesterol concentrations were significantly lower in the rugby players group than in the control subjects. The body weight and body mass index were significantly higher in the rugby players, while the body fat content was only slightly higher in the control group. The serum leptin concentrations in both groups positively correlated with the body mass index and body fat content and also low density lipoprotein concentrations in the control group. The serum leptin concentrations in the rugby players were lower than in the non-sporting subjects despite a similar body fat content in body groups. The possibility that regular hard physical training decreases serum leptin concentrations not only by the decrease of total body fat content, but also by a separate mechanism, which is not directly dependent on the changes in the amount of body adipose tissue.
Maedler, et al. (2003) studied the effect of saturated and monounsaturated fatty acids at different glucose concentrations on human beta-cell turnover and secretory function. Exposure of cultured human islets to saturated fatty acid and/or to an elevated glucose concentration for 4 days increased beta-cell DNA fragmentation and decreased beta-cell proliferation. In contrast, the monounsaturated palmitoleic acid or oleic acid did not affect DNA fragmentation and induced beta-cell proliferation. Moreover, each monounsaturated fatty acid prevented the deleterious effects of both palmitic acid and high glucose concentration. The cell-permeable ceramide analogue C(2)-ceramide mimicked both the palmitic acid-induced beta-cell apoptosis and decrease in proliferation. Finally, each monounsaturated fatty acid improved beta-cell secretory function that was reduced by palmitic acid and by high glucose. Thus, in human islets, the saturated palmitic acid and elevated glucose concentration induce beta-cell apoptosis, decrease beta-cell proliferation, and impair beta-cell function, which can be prevented by monounsaturated fatty acids. The deleterious effect of palmitic acid is mediated via formation of ceramide and activation of the apoptotic mitochondrial pathway.

In a study by Hung, et al. (2003) summarized lower cholesterol and postprandial blood glucose results are associated with viscous fibers. Diets
that are higher in monounsaturated fatty acids, fiber and low glycemic index foods appear to have advantages in insulin resistance, glycemic control and blood lipids in a number of studies. The division of nutrients into total fat (regardless of fatty acids) versus carbohydrate (type and quantity not specified) appears to be less helpful in predicting outcomes.

Furukawa, et al. (2003) investigated the effects of systematic walking on exercise energy expenditure and blood profiles in middle-aged women. Fifty-two female nurse managers, aged 32 to 57 years were randomly assigned to an intervention group and a control group for a 12-week study of the walking program. The exercise energy expenditure was measured using a microelectronic device. Blood profiles were assessed before and after the walking program. The results show that systematic walking increases exercise energy expenditure and improved blood profiles.

Hagberg, et al. (2003) assessed the cross-sectional associations between hormone replacement therapy, habitual physical activity levels and plasma lipoprotein-lipid levels in postmenopausal women, sedentary, active nonathlete and endurance-trained postmenopausal women, with one half the group on hormone replacement therapy. The other half did not receive hormone replacement therapy. The subjects were assessed for plasma lipids, VO$_2$ max, body composition, diet and common genetic variants. It was found
that hormone replacement therapy, exercise training and body composition are associated with plasma lipid levels in postmenopausal women. The common polymorphic variations at key lipid metabolism-related gene loci also may interact with exercise training to affect their plasma lipid profiles.

Kaikkonen, et al. (2002) evaluated the effects of marathon run on different lipid peroxidation measurements, including copper-induced serum lipids and VLDL + LDL oxidation susceptibility, and on plasma total antioxidative capacity, muscular damage and plasma antioxidants in healthy moderately trained 21 male and 25 female volunteers. Blood samples were taken before and just after the 42-km run. In women, baseline levels of several antioxidative compounds (serum albumin and uric acid, plasma free thiols and blood glutathione) were lower, resulting in 21.5% lower plasma total antioxidative capacity and 70.3% higher serum oxidation susceptibility, compared to men. To compare effects in men and women, the exercise-induced variable changes were adjusted for their baseline levels. The results suggested that there are no gender-based differences in exhaustive exercise-induced lipid peroxidation or muscular damage. Secondly, even though exhaustive exercise can increase plasma/serum total resistance towards oxidation, the oxidation resistance of the atherogenic lipoprotein fraction might be diminished.
Fu and Hao (2002) studied the growth and development of adolescents in Hong Kong, to analyze the interrelationship between their development and lifestyle, and to provide some helpful suggestions for lifestyle modification. A total of 404 secondary students ages 12-18 years served as subjects. Morphological measures, blood pressure, blood lipids, aerobic fitness, and body composition were tested. A self-report questionnaire was administered to assess physical activity and dietary habits. It was concluded that, systolic blood pressure and diastolic blood pressure increased with age, and a gender difference was noted. Body height and body weight increased with age. Total cholesterol showed a lowering trend with age, and high-density lipoprotein had a slight rise. The percentage body fat for boys decreased with age but increased for girls. The higher percentage of overweight and obesity was closely associated with physical inactivity and inappropriate food selection such as eating snacks or food rich in fat or cholesterol. Investigators concluded that tailor-made physical activity and nutritional education programs should be designed for adolescents, especially girls during puberty.

The research studies reviewed under subsection biochemical aspects and performance revealed that the regulation of blood glucose level has a multifaceted control by hormones muscle and liver stored glucose levels, glucose extraction and blood flow (Ivey, 1997; Fahay, et al., 1993 and Roef, et
al., 2002). The blood cholesterol levels have been documented to be lower in
trained men and women when compared to sedentary and untrained individuals
(Fu and Hae, 2002 and Haluzik, et al., 1998).

2.5. Haematological Aspects and Performance

In the normal man, the average number of red blood cells per cubic
millimeter is 5200000 (+300000) and in the normal women
4700000 (+ 300000) the number of red blood cells varies in the two sexes and
at the different ages (Pearce, 1993). Also the altitude at which the person lives
affect the normal of red blood cells (Guton, 1991).

Pearce (1993) further states that the adult being has approximately
7000 white blood cells per cubic millimeter of blood. The normal percentage
of the different types of white blood cells are approximately the following:

<table>
<thead>
<tr>
<th>White Blood Cell Type</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poly morpho nuclear neutrophils</td>
<td>62.0 %</td>
</tr>
<tr>
<td>Poly morpho nuclear eosinophils</td>
<td>2.3 %</td>
</tr>
<tr>
<td>Poly morpho nuclear basinophils</td>
<td>0.4 %</td>
</tr>
<tr>
<td>Monocytes</td>
<td>5.1 %</td>
</tr>
<tr>
<td>Lymphocytes</td>
<td>30.3 %</td>
</tr>
</tbody>
</table>

The main reason for white blood cells being present in the blood is
simply to be transported from the bone marrow or lymphoid issue to the areas
of the body where they are needed. Therefore, it is to be expected that the life of the white blood cells in the blood would be short.

According to Morehouse and Miller (1976) the red blood cell is frequently increased in the early stages of exercise probably because of simple hemo concentration (transfer of fluid from the blood to the tissues). During more prolonged exercise fluid passes into the blood and the resulting dilution lowers the red blood cells count. Very strenuous exercise may also cause an increased rate of destruction of red blood cells due to compression of the capillaries by muscular contraction and to increased velocity of blood flow, this is especially noticeable in persons of sedentary habits who sporadically indulge in exercise (Branch, et al, 1999).

Zaumer and Kaplan (1965) in their study took twelve human subjects and assigned them into two groups of equal numbers. One group trained isometrically and the other served as a control. Resting blood samples were taken 1,3,5,7 and eight and half a week after initiation of training. Blood was examined for coagulation time, haemoglobin concentration and for erythrocytes, leucocyte and platelets counts. Packed cell volume were determined before and after training. Scores indicative of muscular strength were recorded throughout training. Isometric training may have produced a chronic diseases in coagulation time. It had no effect on haemoglobin
concentration or on erythrocytes, leucocyte and platelet counts. Increase in scores indicative of muscular strength were statistically significant.

Brotherhood, et al. (1975) investigated haematological, blood volume measurements of 40 male middle and long distance runners and twelve non athletes. The distribution of haemoglobin concentration, packed cell volume, erythrocyte count, total ironbinding capacity, serum and erythrocyte folate and serum vitamin B12 concentrations were essentially the same in atheletes and non-athletes. The mean serum iron concentration was higher in non-athletes than in athletes. There was no difference in the above measurements between athletes taking iron and/or folate and athletes not taking these supplements. Blood volume and total body haemoglogin were on average 20% higher in the atheletes than in the non-athletes. There was no correlation between haemoglobin concentration and blood volume in athletes. The evidence of this study suggests that haemoglobin concentration and blood volume are independently controlled. The. 2,3-Diphosphoglycerate concentration in the erythrocytes was higher in the athletes than in the non-athletes.

Gonzalez, et al. (2002) investigated if ATP could be a signal by which the erythrocyte contributes to the regulation of skeletal muscle blood flow and oxygen delivery. To achieve this purpose circulating ATP in eight young subjects were measured during incremental one-legged knee-extensor exercise
under conditions of normoxia, hypoxia, hyperoxia, and CO+normoxia, which produced reciprocal alterations in arterial O₂ content and thigh blood flow (TBF), but equal thigh O₂ delivery and thigh O₂ uptake. With increasing exercise intensity, it was found that the erythrocyte functions as an O₂ sensor, contributing to the regulation of skeletal muscle blood flow and O₂ delivery, by releasing ATP depending on the number of unoccupied O₂ binding sites in the hemoglobin molecule.

Schumacher, et al. (2002a) studied hemoglobin, hematocrit, blood cell variables and changes in vascular volumes in male and female national team cyclists to evaluate the influence of exercise on these variables and the results of blood tests, and to estimate normal ranges in athletes for blood tests. It was found that athletes displayed seasonal adaptations in their blood profile which should be considered in testing regulations. The average haemoglobin level was 15.4 g/dl for male and 13.9 g/dl for female cyclists and can be used as reference values for single and multivariable blood tests.

Schumacher, et al. (2002b) investigated the characteristics of the red blood cell system and the iron metabolism in athletes of different sporting disciplines and at different levels of performance. It was found that physical training had no significant effect on haemoglobin and haematorit variables in athletes compared with untrained controls. The specific type and duration of
exercise is of major importance in the adaptations of the blood cell system and the iron metabolism.

Cullinane (1979) for his study took fifteen members of the men’s variety cross country team as subjects. Blood samples were taken from the subjects twenty times during the courses of the season. Each sample was analysed for haemoglobin content, red cell count and white cell count. The subject times from six competitive meets were recorded. Analysis were made by zero order correlation and multiple correlation. The conclusion were given as a single measure of haemoglobin. White cell count or red cell count taken prior to a meet does not accurately predict running performance. The change in blood components from one readings to the next just prior to a week is not a good indicator of running performance. The average value of several readings of blood components prior to a meet does not accurately predict running performance although the findings were contradictory in this analysis.

Rietjens, et al. (2002) conducted a study to determine changes in haematological variables during long-term endurance training, detraining and altitude training in elite Olympic distance triathletes. The haemoglobin, haematecrid, red blood cell count and plasma ferritus were measured on seven male and four female athletes during off season, training season and race season. It was concluded that long term endurance training did not largely alter
haemoglobin status but increased during training season. Screening of haematological variables were suggested as many athletes have had near or below the lower limit of the normal range. The data obtained from altitude training suggested that training at a minimum altitude of 2600 m for three weeks was necessary to alter haemotological status.

Heinicke, et al. (2001) conducted a study to determine whether athletes from different disciplines are characterized by different blood volumes and the extent the blood volume can possibly limit endurance performance within a particular discipline. Ninety four male elite athletes were divided into the following six groups, viz.: downhill skiing, swimming, running, triathlon, cycling junior and cycling professional. Two groups of untrained subjects and leisure sportsmen served as controls. Total hemoglobin and blood volume were measured by the corebreathing method. In comparison to controls total hemoglobin and blood volumes were about 35 - 40 % higher in the endurance groups running, triathlon, cycling junior and cycling professional. Within the endurance groups there were no significant differences. The anaerobic discipline downhill skiing was characterized by very low blood volume. Swimming had an intermediate position probably because of the immersion effects during training in the water. The \( \text{VO}_2 \text{max} \) was significantly related to total hemoglobin and blood volume not only in the whole group but also in all
endurance disciplines. The reasons for the different blood volumes are an increased adaptation to training stimuli and also individual predisposing genetic factors.

Branch, et al. (1999) conducted a study to find out whether greater hematologic changes would be induced in women by higher exercise intensity during endurance training. Twenty six healthy, sedentary female were classified into high intensity or low intensity and control and cycle ergometer training groups. Twelve weeks training was given to the subjects and the following variables, namely, energy expenditure, plasma volume, calculated total blood, red blood cell volume, total haemoglobin and erythropoietin concentration were measured. It was concluded that endurance training did not increase in plasma volume, total blood volume, red cell volume and total hemoglobin in previously sedentary females regardless of the intensity of training and a decrease in haemoglobin, red blood cells and haemotocrit values were observed.

Douglas (1989) conducted a study to find out the effect of competition and training on the hematological status of women field hockey and soccer players. Thirty collegiate athletes participated in the 14 weeks study. Blood samples were drawn prior to the start, mid-point, and end of the sport season. The mean values for hemoglobin, hematocrit, mean corpuscular volume, and
red blood cell count increased over time for both experimental and control groups and the values for all hematological parameters were within the normal ranges for females and it was concluded that "sports anemia" was not present.

Popichev (1999) determined influence of the preparation "Polyen" has been studied on indexes of lipid acids contents in blood plasma, erythrocyte membrane and serum albumin of high-qualified volleyball-players. It was shown that "Polyen" has favourable effect on different metabolic pathways of lipid acids, that allow to recommend this preparation as additional component in food ration for training sportmen. Professional volleyball players given biopreparation "Polien" containing polyunsaturated fatty acids glycolysis and pentose phosphate pathway reactions are intensified and glutathione reductase activity decreased. At the same time the affinity of haemoglobin to oxygen stabilized in the sportsmen before and after intensive exercises.

**Leukocytes**

It has been documented by many researchers that exercises increases both athletes and non athletes resistance to infection. However there are conflicting results regarding the relationship between acute and chronic exercise and immune function and also between the intensity, duration and frequency of exercise and immune functions (Field, et al., 1991; Lewicki, et al., 1987 and Benoni, et al., 1995a).
Lewicki, et al. (1987) conducted a study on 20 conditioned cyclists and 19 untrained men during exercise stress. At rest absolute and percent number of neutrophils, eosinophils, and monocytes and neutrophil bactericidal activity were similar in sportsmen and untrained men, while neutrophil adherence was lowered in sportsmen. Maximal physical exercise induced significant increases in absolute numbers of neutrophils and monocytes in both groups. In sportsmen, adherence of neutrophils and monocytes and neutrophil bactericidal activity significantly decreased during physical exercise, while neutrophil phagocytic activity did not change. On the other hand, in untrained men, maximal physical exercise did not induce significant changes in neutrophil and monocyte adherence and bactericidal activity of neutrophils. The results obtained suggest that intensive physical exercise tends to depress nonspecific immunity, which may render sportsmen more susceptible to infections.

The effects of cycle ergometer exercise, its exhaustion and during recovery on 12 healthy males was investigated by Field, et al. (1991) on circulating mononuclear cell numbers. At exhaustion the total leukocytes levels increased significantly (p <0.05) but returned to pre exercise levels at one hour during recovery except for lymphocytes which were lower than the pre exercise levels. The total leukocyte counts with exercise were significantly related to plasma epinephrine concentration.
Benoni, et al. (1995a) investigated in seven professional basketball players on possible changes before, during and after the sports season, in haematological parameters and in the phagocytic process of neutrophils, such as, adhesion, superoxide anion release and bactericidal activity. Training and competitions produced a significant rise in the number of total leukocytes and differential counts, but the values returned to the pre-start levels three weeks after the end of the season. The bactericidal activity were significantly greater during the sports season, while the percentage of cellular adhesion significantly decreased during the competition and after the sports season the values returned to the control levels.

Benoni, et al. (1995b) studied the possible effects of acute exercise on some haematological parameters and functions of neutrophils in seven active and six inactive subjects. Ten minute cycle ergometer exercise at a heart rate of 150 beats/min induced a significant increase in total leucocyte, lymphocyte and neutrophil concentrations in active subjects and the serum iron and ferritin concentrations were lower in active when compared to inactive subjects. Cellular adhesion, bactericidal activity and superoxide anion production did not change after exercise. The neutrophils from active subjects showed a significantly higher percentage of adhesion, higher bactericidal activity and lower superoxide anion production. It was concluded that the training induced
changes in some neutrophil functions, while acute exercise influenced, overall, leucocyte concentrations

The effects of eccentric exercise on changes in numbers of circulating leukocytes, cell activation, cell adhesion, and cellular memory function were investigated in 12 men, aged 22-35 years by Malm, et al. (1999). The immunologic effects of postexercise epidermal treatment with monochromatic, infrared light were also evaluated. Blood was drawn before and during 6, 24, and 48 hours after exercise for phenotyping and analysis of creatine kinase activity. The leukocyte, monocyte, and neutrophil number decreased with no change in the number of basophils, eosinophils, B cells, and T cells, and there was a decrease in natural killer cell number during post exercise. Correlations between immunologic and physiological parameters indicate a role of the immune system in adaptation to physical exercise.

Pedersen and Steensberg (2002) studied the effect of exercise and hypoxia on leucocytes subpopulations and found that after the stress, the number of lymphocyte declines whereas the neutrophil number continues to increase. When exercise was performed during hypoxia, the exercise induced immune changes were pronounced. The evidence that the exercise and hypoxia induced changes in leukocyte subpopulations are mediated by
neuroendocrinological factors such as catecholamines, growth hormone, and cortisol needs to be further investigated.

Nemet, et al. (2003) conducted a study to determine the acute exercise-induced alterations in the growth hormone, insulin like growth factor-1 axis, inflammatory cytokines and certain aspects of immune function in a group of adolescent girls after a typical water polo practice. This study demonstrated that an intense "real-life" exercise bout in adolescent females leads to profound increases in inflammatory cytokine and reductions in anabolic mediators with substantial alterations in white blood cell subpopulations and adhesion molecules.

Mooren, et al. (2002) conducted a study to analysis lymphocyte apoptosis after exhaustive and moderate exercise. Blood samples taken before, immediately after and one hour after the treadmill exercise tests performed at 80% maximal oxygen uptake until exhaustion and 60% maximal oxygen uptake with identical running time were analysed. The results suggested that apoptosis might contribute to the regulation of the immune response after exhaustive exercise and more investigations need to conducted to determine, whether deletion of autoreactive cells are beneficial or harmful.
Bishop, et al. (2001) conducted a study to find the influence of ingesting carbohydrate beverages during heavy exercise is associated with smaller shifts in numbers of circulating neutrophils and attenuated changes in neutrophil functional responses. The pre-exercise carbohydrate status influences neutrophil trafficking but not function in response to prolonged cycling.

Domej, et al. (2002) investigated the effect of endurance exercise at moderate altitude on levels of circulating eosinophils, serum eosinophil cationic protein, serum osmolality, and dynamic pulmonary function parameters in healthy mountaineers. Results provide strong evidence for nonspecific activation of blood eosinophils during prolonged intense aerobic exercise at moderate altitude, modifying both eosinophil dynamics and regulation of eosinophil cationic protein release in healthy subjects.

Zavorskey, et al. (2002) conducted a study to determine the relationship between the right-to-left ventricular red cell pulmonary transit times during intense exercise and circulating white blood cell counts in highly trained endurance athletes. The study suggested that athletes with higher circulating numbers of white blood cells during pre exercise have faster (shorter) red cell transit times through the lung during intense exercise.
In haematological parameters the haemoglobin, haematocrit and red blood cell count increased with training (Schumacher et al., 2002a and Rietjens et al., 2002) with endurance cyclist showing the greater gain (Branch et al., 1999). The exercise and training induced leukocyte increase (Pederson and Steensburg, 2002 and Mooren et al., 2002).