CHAPTER II

REVIEW OF RELATED LITERATURE
A search for knowledge can not yield something meaningful if its relation with the existing knowledge has not been examined. A research study is never conducted in a vacuum. Hence, an attempt was made, as far as possible, to find out what has already been done. A review of literature gives both thematic as well as methodological direction. In a rare case, a study may justify accomplishment of a new knowledge without paying attention to what has been done earlier. In an age where we already find vast store of knowledge, it is necessary to examine what has been done before we boast of a new achievement (Barotia and Sharma, 1999). Hence, a brief review of the studies related to the present problem is described in this chapter.

STUDIES RELATED TO PLASMA CORTISOL

Frenkl et al. (1994) stated that the rats trained by regular swimming or running exercise was found to respond to a smaller rise in corticosterone level in previous animal experiments. Any exhaustion of the adrenal cortex could be ruled out: trained animals gave a maximum response to adrenocorticotropic hormone (ACTH). Estimation of circulating ACTH corroborated the above observation; ACTH response to exercise was smaller in the animals adapted to it.
Frenkl et al. (1994) also stated that observations made in humans differed from those obtained in the animal studies. Sub maximum intensity exercise did produce no rise in plasma cortisol in the various age and event groups. Statistically significant rises of plasma cortisol were found during maximum intensity exercise in such adult athletes that showed very high levels of endurance fitness. In contest situations, the rise of plasma cortisol was considerably greater which was regarded as indicative of the interplay of emotional factors. Stress hormones and testosterone were estimated before and after an all-out exercise in junior age judoists. Physiological parameters showed these athletes with a training history of four to five years to have high working capacity in addition to good sports performance. All stress hormones rose significantly, ACTH the most. Testosterone levels did not change or decrease slightly and not significantly.

Atko and Tonis (1985) studied the adrenocortical activity in rats during three weeks of swimming exercise with the training load being increased each week. Adrenocortical activity increased during the first set of every new level of exercise. A high level of activity remained present both at rest and after exercise during the next few days’ exercise at this new level. Further exercise found subtotal depletion of adrenocortical reserve levels with the eventual restoration of
normal levels of adrenocortical levels without any further response to the same exercise load.

Theintz et al. (1995) distinguished the hormonal response to a short but intense session of physical exercise from the endocrine adaptation to systematic physical conditioning. The normal child was perfectly equipped to handle stress situations such as those generated by leisure sport; the training increase in stress hormone has no negative effect on growth and puberty. In young elite athletes as for adults, the alterations of the endocrine system result from an inappropriate physical conditioning programme for the individual level of tolerance, whereas the gonadal function was predominantly affected. Alterations of growth hormones have also been reported.

Corral et al. examined serum and salivary cortisol responses to cycling exercise in male children. Each child performed a graded exercise test on a cycle ergometer to determine VO$_2$$_{max}$. On a separate day, a 30-min bout of exercise at 70% of VO$_2$$_{max}$ was performed. Blood, obtained from a venous catheter and saliva samples were collected at rest, at 15 and 30 min of exercise and 15 min post-exercise. The mean serum cortisol level at 15 min and 30 min of exercise and at 15 min. post excretes were significantly greater than rest. The increase in salivary cortisol levels over time approached, but did not reach significance. However, the increase in salivary cortisol at 30 min of exercise and 15 min post-exercise was similar to the change in serum cortisol at these same two time points. Scrum and
Salivary cortisol were correlated at 15 min of exercise, 30 min of exercise and 15 min post-exercise, but not at rest. In conclusion, 30 min of submaximal exercise at 70% VO$_{2\text{max}}$ significantly increased serum cortisol level. Further salivary and serum cortisols were correlated during and after exercise.

Salcedo (1993) examined serum and salivary cortisol during and after aerobic exercise. Ten male children came to the laboratory on three occasions. The first visit was to familiarise the child to perform a maximal exercise test on a cycle ergometer (mean VO$_2$ = 49.5 ± 3.6). On the second visit, each child to perform a maximal exercise test (mean VO$_2$ = 49.5 ± 3.6). On the third visit, an indwelling catheter was placed in a forearm vein. Thirty minutes later, baseline blood and saliva samples were obtained followed by thirty minutes of exercise on a cycle ergometer at 69.5 ± 3.0% of VO$_2$$_{\text{max}}$. Blood and saliva samples were obtained at mid-exercise, end exercise and 15 minutes post-exercise. Serum and salivary cortisol were analysed using RIA kit. A repeated measures ANOVA revealed that exercise significantly increased serum, but not salivary cortisol. It was concluded that salivary and serum cortisols were strongly correlated during and after exercise in children.

Ronkainen et al. (1986) investigated the long-term effects of endurance exercise on the function of the adrenal cortex of 18 female runners and 12 control subjects and 13 joggers and 11 control subjects, which were found by measuring
the serum concentrations of cortisol and dehydroepiandrosterone sulfate and the responses of cortisol to intravenous ACTH injection. All of the participants were studied over one menstrual cycle during light training in the autumn and hard training in the spring. The mean spring versus autumn concentrations of cortisol was significantly increased in runners during the follicular and luteal phases of the menstrual cycle. Chronic endurance exercise did not appear to alter the function of the adrenal cortex, while an undefined spring-associated factor, possibly the high luminosity, appeared to induce an increase in cortisol secretion in female runners.

Keizer et al. (1989) investigated 25 males and 11 females under 18 to 20 months-training periods during which the training distance was gradually increased. The training period was divided into three periods of 5, 6 and 7 months respectively. The first, second and third period was concluded with a 15, 25 and 42-km road race respectively. Before and after three contests of 15, 25 and 42.195km, the plasma concentration of testosterone, cortisol and dehydroepiandrogen sulfate (DHEAS) was determined. The decrease of plasma testosterone concentration in males was dependent on the distance of the contests. Moreover, the plasma testosterone concentration was increased in males during the course of the training period. In females, no clear relation between plasma testosterone levels and the contests could be observed. DHEAS seems to be a
more useful stress marker than the plasma cortisol concentration. The amplitude of DHEAS increment was greater after the marathon.

Stupnicki et al. found post-exercise values of blood lactate concentration, pH, oxygen uptake, heart rate, power output and pre and post-exercise blood cortisol concentration of 74 male and 40 female athletes (wrestlers and senior and junior rowers). The senior rowers, junior rowers and wrestlers had different exercise protocols. The senior rowers of both sexes had significantly higher rest concentrations of serum cortisol than the junior athletes. A significant correlation between post exercise lactate concentrations and pre-exercise concentrations was found in all the male group, but not in the female ones. It was concluded that the pre-exercise cortisol concentration might condition anaerobic-glycolytic metabolism in physical exercise.

Migdadi et al. (1996) designed a study to examine the effects of exercise on adrenocorticotropic hormone (ACTH) and cortisol at low altitude (350 m below sea level) and to compare these effects with those at a moderate level altitude (620 m above sea level). Ten male trained athletes participated in a 21-km non-competitive race. Serum levels of ACTH, luteinising hormone (LH), growth hormone and cortisol were measured before and after the race at each of the altitudes. A significant increase in serum levels of ACTH was observed in response to this exercise only at lower altitude. Serum levels of growth hormone
were increased at both altitudes. Those of LH were not affected. Serum cortisol levels were increased following exercise at both altitudes. It was proposed that ACTH may play a role in acclimatization to exercise at low altitudes. The role of growth hormone and LH in this conditioning process seemed insignificant.

Bonen (1976) studied excretion rates of urinary free cortisol in twenty men assigned to four treadmill exercise groups walking at 3 mph or 30 min, running at 7.5 mph for 10 min or 30 min. Free cortisol in urine was measured before and 30, 60 and 90 min after exercise and again on a control day. Patterns of free-cortisol excretions after exercise at 7.5 mph for 10 and 30 min were significantly different from the control day (p less than 0.05) with the largest changes occurring in the 30-minute group. Exercise and control patterns were not different for the other two conditions (p greater than 0.05). Cortisol excretion rates were directly related to the relative intensity of exercise and the respiratory exchange ratio. It was concluded that changes in free cortisol excretion rates depend on the duration as well as the intensity of exercise.

Braudenberger and Follenius (1982) and Sulton et al. (1988) found considerable variability in the cortisol response to exercise depending on many factors that include exercise intensity and duration, fitness level, meal status and even circadian rhythm. Even at lower work rates, plasma cortisol rises if the exercise period is sufficiently long.
Buono et al. (1986) determined the intensity threshold needed to elicit increase in plasma aldosterone and cortisol during graded exercise in human. Seven male volunteers performed a maximal oxygen uptake (VO2 max) test on a cycle ergometer, plasma levels of aldosterone, cortisol, angiotensin II, ACTH and potassium were measured at rest and at each 50 w workload of the exercise test. The results showed that aldosterone significantly increased from a mean of 231 ± 22 p mol. l⁻¹ at rest to 464 ± 22 p mol. l⁻¹ at exhaustion. Cortisol significantly increased from 284 ± 38 n mol. l⁻¹ at rest to 311 ± 39 n mol. l⁻¹ at exhaustion. Cortisol was only significantly increased at exhaustion. Interestingly, potassium, ACTH and angiotensin II were all significantly correlated with aldosterone during exercise.

Viru et al. (1994) studied forty-nine healthy subjects in order to establish the dynamics of endorphin levels in blood during prolonged exercise. The sample was composed by 20 endurance athletes, 10 amateur joggers and 19 untrained subjects. The concentration of beta – endorphine, alpha and gamma – endorphine as well as corticotropin and cortisol were determined by radio immuno assay. The following common variants of dynamics of beta – endorphine level were found: 1) an increase during the first 30 minutes followed by a decrease below the initial values 2) a biphasic increase 3) decrease during the whole period of exercise. The biphasic increases in case of trained subjects whereas decreases in case of untrained.
Premo (1992) analysed select regulatory hormonal responses [testosterone (t), luteinizing hormone (LH), prolactin (PRL) and cortisol (CO)] in moderately trained males over an 8 hour recovery period following anaerobic (ANA) and aerobic (AER) exercise sessions of equal total work output. Subjects initially performed a maximal aerobic capacity (VO2 max) test to determine an overall workload for experimental sessions. On subsequent testing days, subjects were randomly assigned to one of the following experimental sessions: a) rest for 60 minutes (CON), b) cycle at 60% VO2 max for 60 minutes (AER), or c) 2 minute alternate cycling intervals at 110% and 40% VO2 max (ANA). Blood samples were obtained just prior to the experimental session, immediately following and every hour for eight hours in the recovery. Statistical analysis revealed significant increase in prolactin and cortisol only due to exercise.

Golan (1993) made twofold investigation: a) to determine if high intensity intermittent treadmill exercise at 90% of maximal oxygen uptake (VO2max) would elevate the levels of lactate, adrenocorticotropic hormone (ACTH), cortisol, beta-endorphin, dehydroepiandrosterone sulfate and arginine-vasopressin and b) to determine if thymopentin would attenuate these elevations at rest, during and after the exercise. The study was conducted in two phases. Ten male subjects took part in phase I that tested the first aforementioned purpose. Blood samples were taken
five minutes prior to, immediately post, 30, and 120 minutes post-exercise. Data was analysed using a 1 (treatment level) x 4 (time levels) analysis of variance (ANOVA) design with the probability of 0.05 considered significant. Twenty male subjects participated in phase II that tested the second purpose. Subjects were subcutaneously administered either 50 mg thymopentin or saline placebo and 24 hours later performed the exercise task of phase I. Data was analysed using a 2 (treatment levels) x 4 (time levels) ANOVA factorial design with the probability of 0.05 considered significant. Exercise in phase I resulted in significant elevation of plasma ACTH, argininevasopressin, b-endorphin and lactate immediately post exercise. Serum cortisol was significantly elevated at 30 minutes post exercise. It was concluded that intermittent exercise at 90% VO_{2 max} was sufficient to increase the circulating levels of lactate and hormones of the hypothalamic-pituitary-adrenal axis (HPA) examined.

Obminski et al. (1994) investigated 28 junior male rowers divided into two equal groups and they performed laboratory exercises on a rowing ergometer on two consecutive days. Group one, which performed a maximal exercise simulating the 2-km race, was examined on the first day. Group 2, which performed submaximal exercise, was examined on the second day. Venous blood was withdrawn just before and three minutes after exercise. Saliva was also sampled before exercise and then 3, 15, 30, 45 min. after exercise. The cortisol
levels were found and correlated with power output, amount of work and blood lactate. Correlations between post-exercise concentrations of cortical and exercise performance indices were not significant except in group 1 where a relatively strong correlation was found between serum cortisol and total work output. Salivary cortisol may serve as an excellent index of the glucocorticoid functional status.

Ponjee et al. (1994) investigated the effect of prolonged physical stress on peripheral androgen turnover. Venous blood samples were taken from 18 athletes 24 hours before finishing a competitive marathon run and directly after running the race. Serum cortisol, testosterone (T), dehydroepiandrosterone sulfate (DHEAS) and sex hormone binding globulin (SHBG) were determined. Marathon running causes a rise in serum cortisol concentration in all athletes. Furthermore, a significant rise in serum T and T-index was observed. The significant rise in serum DHEAS concentration pointed towards stimulation of the adrenal cortex or a reduced hepatic metabolic clearance rate. The marathon running leads to increased concentrations of serum adrenal and gonadal androgens.

Rudolph et al. (1998) reported that physically active individuals demonstrate attenuated cortisol responses to acute exercise compared to inactive individuals. The study was conducted between 13 male cross country runners and
13 non-runners for studying the role of activity in effective responses to acute exercise. The experimental trial consisted of a 30-min treadmill run at 60% VO$_{2\ max}$. Cortisol and affective responses were assessed before, during and after exercise; rates of perceived exertion (RPEs) were recorded during exercise. Analysis of variances indicated no significant group differences in cortisol responses. However, there was no main effect for time (p < 0.05) with cortisol increasing from baseline to the 29th minute of exercise and then decreasing to 30th minute post-exercise. Non-runners possessed greater perceptions of effort and negative affect during exercise compared to cross-country runners. Furthermore, the RPEs were positively related to post-exercise cortisol levels (p < 0.05) and affect and cortisol responses were inversely related to 30 min post-exercise (p < 0.05). These results provided partial support for the hypothesis that cortisol levels are related to exercise-induced affective states.

Andrews (1998) determined the influence of acute ingestion of low versus high glycemic-index-carbohydrate breakfast foods on exercise performance and on fat metabolism. Seven endurance-trained subjects completed three endurance trials, one hour after consuming either rice clex cereal, all-bran cereal or water. They ran on a treadmill for 90 minutes at 70% VO$_{2\ max}$ followed by a run to exhaustion. VO$_2$ responses, blood levels of cortisol and lactate did not differ
between trials. In conclusion, glycemic index had minor effects on fat metabolism, with no influence on performance.

Lundberg (2000) examined the effects of different forms of carbohydrate with protein, following a resistance training bout, on markers of substrate levels and catabolism markers on post-recovery. Thirty-nine resistance-trained subjects were recruited. During familiarisation session, one repetition maximum (1 RM) was determined on the chest press, seated row, shoulder press, lat pull, leg extension, leg curl, biceps curl, triceps extension and leg press. On a separate day, subjects returned 11.5 hours fasted, donated a fasting blood sample and completed 3 sets of 10 at approximately 70 % 1 RM with two minutes rest between sets and exercise. Immediately following exercise, subjects were randomly assigned to a non-supplemented control (c) group or to ingest one of three carbohydrate / protein shakes consisting of 16 ounces of water mixed with either 120 g honey (H), maltodextrin (M) or sucrose (S) and 40 g of whey protein. Blood samples were collected at 30, 60, 90 and 120 minutes post supplementation and analysed for glucose, insulin, cortisol, testosterone as well as muscle and liver enzymes. Data were analysed by two-way ANOVA for repeated measures, with LSD and Tukey post-hoc analysis used as needed. Results showed that there was no significant difference in total volume of the workout between groups. Exercise elicited significant changes in cortisol, muscle and liver enzymes. Significant
interactions were observed among groups in insulin, creatine and in the ratio of creatine. The findings showed that different forms of carbohydrate or protein supplements after resistance training might have an impact on the anabolic hormonal profile during recovery.

Buono et al. (1986) examined plasma adrenocorticotropic hormone (ACTH) and cortisol levels following brief high intensity exercise in order to analyse the response of the hypothalamic-pituitary-adrenocortical axis to exercise. Six male subjects attended two testing sessions, before which they refrained, from food and exercise for eight hours. For the first session each subject performed an incremental load (25 w/min.) exercise test to exhaustion on a cycle ergometer while for the second session one minute bout of exercise on a cycle ergometer at 120 percent of the previously determined oxygen consumption rate was performed. Blood samples were collected at rest, immediately following the exercise bout, as well as at 5, 15 and 30 minutes post-exercise. The results of the analysis show that brief high intensity exercise results in significant increase in plasma ACTH and cortisol levels.
STUDIES RELATED TO PLASMA SODIUM

Matwichuk et al. (1999) measured changes in rectal temperature and hematological, biochemical blood gas and acid-base values before and after exercise. Fourteen healthy dogs exercised continuously for 10 minutes by retrieving a dummy thrown ball approximately 10 to 50 yards on land. Rectal temperature, pulse, respiratory rate, serum biochemical profile, arterial blood gas tensions, acid-base status, plasma lactate and pyruvate concentrations were measured at rest and immediately after exercise. The results showed that significant increases were found in RBC, WBC, hemoglobin, total protein and serum sodium and potassium concentrations.

Shi (1990) studied eight well-trained male and female cyclists to determine the effect of sodium and/or water intake on plasma aldosterone during six hours of cycling in a warm environment. Each subject randomly completed three trials (water-W; saline-S and no fluid-NF) at one-week intervals. Venous blood samples were obtained before dehydration, at 2, 4, 5 and 6 hours during exercise and also after dehydration. Plasma samples were collected for hemoglobin, sodium, potassium, aldosterone and osmolality. Sweat and urine samples were also collected and analysed for sodium content. Plasma volume based on hemoglobin decreased significantly at 15 min in all the three trials. Plasma sodium increased in trial no fluid due to plasma volume loss. Significant
differences in sodium were found between trial NF and trial W or trial S. Average total sodium content of plasma decreased by 125.9 mEq during trial S, 223.1 mEq during trial W and 147.1 mEq during trial NF. Plasma potassium increased significantly at 2 hours in all trials. Plasma aldosterone increased significantly during exercise and decreased after exercise.

Schmidt et al. (1999) found the influence of exercise and environment on the electrolyte and water status in hypoxic adapted subjects. They investigated eleven well-trained marathon runners native to an altitude above 2600m, before and after two marathon races, one completion was held at moderate altitude (1650m) and another under tropical condition (470m). Blood samples were taken 3h before, immediately after, 1h after and 24h after the races. The loss in body fluid was calculated to be 2.15 L in moderate altitude and 5.05 L in tropical conditions respectively. It was compensated mostly by ingested fluids without electrolyte context and by metabolically produced water, which led to hyponatremia in moderate altitude from 144.3 ± 0.7 to 131.7 ±2.1 m.mol.¹. Serum hormone concentrations and serum aldosterone concentration significantly increased during both races. Under hypoxic condition, they found that hyponatremia had developed. This can be partly explained by pure water intake and metabolically produced water, and possibly, by a special hypoxic-induced effect.
STUDIES RELATED TO PLASMA POTASSIUM

Castenfors (1967b) found that the renal potassium excretion was increased with heavy exercise. This consistency may be related to renal blood, that is, renal blood flow must have been decreased below a critical level.

Castenfors (1967a) also found that the changes in potassium excretion were apparently not consistent with changes in excretion of other electrolytes during exercises. No change in potassium excretion was reported with 45 minutes of sub-maximal supine exercise.

Castenfors (1967a) and Grimby (1965) studied fourteen males during 45 minutes periods of submaximal bicycle ergometer exercise. Urinary sodium excretion decreased significantly during exercise. This decrease was about 50% of resting level. The decrease is thought to be associated with an increase in tubular reabsorption, which may be secondary to changes in the hormone aldosterone. Sodium, chloride and water excretion were found to be depressed 24 to 48 hours following 60 minutes of exercise at about 60% VO₂ max. This response was thought to be only partly related to aldosterone, since aldosterone levels returned to normal within 6 to 12 hours.

Hazeyama and Sparks (1979) and Carlsson (1978) found that exercise was uniformly associated with a rise in plasma potassium concentration. The healthy
young subjects, exercising on a treadmill at 40 to 50 per cent of their maximum work intensity, experienced a rise in plasma potassium concentration by 0.5mEq/liter, due to a shift of potassium from intra-cellular to extra-cellular space.

Bia and De Fronzo (1981) studied a variety of factors including semmtonicity, acid-base balance, exercise, and circadian rhythm. That influenced the extra renal potassium balance. Hypertonicity is thought to increase serum potassium, because as water moves out of cells in response to the osmotic gradient, potassium is brought with it by solvent drag. Plasma potassium increases with exercise.

Mcconell et al. (1999) recently conducted a study to examine the effect of fluid ingestion volume on heart rate, rectal temperature, plasma electrolytes and performance during intense endurance exercise at 21° C. Eight well-trained men cycled for 45 minutes. The 45 minutes exercise bout was followed immediately by a 15 minutes 'all-out' performance ride. Reductions in plasma volume and increase in plasma sodium and potassium concentrations during exercise were largely unaffected by fluid ingestion. Fluid ingestion had no significant effect on heart rate, body temperature, plasma volume, plasma electrolytes or performance.

Carney (1999) investigated the effects of acute and chronic exercise on serum potassium levels in hemodialysis (HD) patients. The study tested hypothesis
that an extended period of exercise bout will have no effect on the rise in k during an acute exercise bout in HD patients. Forty-five patients were randomised into low and high hemoglobin groups and further randomised into control and exercise groups. The exercise groups were trained three times a week for 3 months. All groups of patients were tested on a cycle ergometer at increasing levels of difficulty, at the study initiation and after 3 months. The results of the study indicated a significant increase in serum k during acute maximal exercise in all groups.

Adrogue and Madias (2000) found that the serum sodium and potassium concentration and serum osmolality are closely controlled by water homeostasis, which is mediated by thirst, arginine vasopressin and the kidneys. A disruption in the water balance is manifested as an abnormality in the serum sodium or potassium concentration. Further Adrogue and Madias opined that hypernatremia represents a deficit of water in relation to the body’s sodium stores, which can result from a net water loss or a hypertonic sodium gain. Net water loss accounts for the majority of cases of hypernatremia. It can occur in the absence of a sodium deficit (Pure water loss) or in its presence (hypotonic fluid loss). Because sustained hypernatremia can occur, only when thirst or access to water is impaired. Hypernatremia in infants usually results from diarrhoea. Thirst impairment also results in hypernatremia.
SUMMARY OF LITERATURE

The ACTH response to exercise was smaller in the animals but in athletes ACTH rose significantly. Children and young elite athletes showed significant increase in stress hormones. Male children showed elevation in plasma cortisol after the cycling exercise though the salivary cortisol did not rise significantly.

Female runners showed significant increase in cortisol but it was opined that the high luminosity appeared to induce an increase in cortisol secretion rather than endurance exercise. Dehydroepiandrosterone sulfate was found to be a more useful stress marker than plasma cortisol when male and female groups were compared in exercise simultaneously. There was a higher rest concentration of serum cortisol found in senior rowers of both sexes than junior rowers of both sexes.

It was also identified that serum cortisol levels were increased following exercise at low altitude (350 m below sea level) and moderate level altitude (620 m above sea level). It was found that ACTH might play a role in acclimatisation to exercise at low altitude.

It was concluded that changes in urinary free cortisol excretion rates depend on the duration as well as the intensity of exercise. The significant increase was due to exhaustion after marathon in cortisol level than in aldosterone, angiotensin II, ACTH and potassium. It was identified that intermittent exercise at 90 % $\text{VO}_{2\text{,max}}$ was sufficient to increase the levels of lactate and hormones of the
hypothalamic-pituitary-adrenal axis. Marathon running caused a rise in serum cortisol concentration in all athletes.

It was also noted that brief high intensity exercise results in significant increase in plasma ACTH and cortisol levels. As the competitive game of basketball requires both aerobic and anaerobic components (Berger, 1982), basketball game may be considered under brief high intensity exercise.

Increase in RBC, WBC, total protein and serum sodium and potassium were noted following 10 minutes exercise of ball retrieving among dogs. In case of athletes, plasma sodium and potassium increased immediately following exercise. Plasma potassium concentration decreased in moderate altitude (1650 m). This indicates that hyponatremia was developed under hypoxic condition. Hyponatremia represented a deficit of water in relation to the sodium stores of the body. Net water loss accounts for the majority of cases of hyponatremia. Few studies, if any, have been done in this topic. Hence, the investigator was interested in taking up this study.