Chapter II

REVIEW OF RELATED LITERATURE

The known facts build up the edifice of the new theories and principles. Review of research studies serve as buckle between the old and new, between the known and unknown. It is a milestone leading the research on the high road of future. Review of literature develops researcher insight and establishes his intellectual superiority over others. A study of relevant literature is an essential step to get a good comprehension of what has been done with regard to the problem under study. “The literature in any field forms the function upon which all future work will be built”. The literatures relevant to the present study that have been collected from different sources of reference are described in this chapter under the headings as follows:

1. Physical fitness and physiological demands on hockey
2. Seasonal variations in physical fitness variables of hockey players
3. Seasonal variations in physiological variables of hockey players
4. Maturational changes in muscle strength

**Physical fitness and physiological demands on hockey players**

Wein (1981) provided some early data quantifying the distances covered during hockey matches in the 1972 World Cup. The range of distances was 5.14km to 8.82km with an average of 5.61km but scant details of methodology were given and it is unclear if the data included of players who played for less than 70 minutes.
Ghosh et al (1991) reported descriptive information from an Indian national team training camp that saw 54 junior and senior players involved in a series of fitness assessments and trial matches. Average VO$_2$max was 54.4 ml.kg.min$^{-1}$ for the junior players and 53.8 ml.kg.min$^{-1}$ for the senior players. To gain an insight into match intensity blood lactate samples and HRs were recorded. Blood lactates, taken two minutes after the end of a match were between 4 and 6 mmol.l$^{-1}$ and mean match HRs were 143.4 ± 15.3 b.min$^{-1}$ for the junior players and 156.6 ± 15.1 b.min$^{-1}$ for the senior players. Although the post-match lactate sample is not necessarily indicative of match intensity it does provide a general gauge and in conjunction with the HR data suggests a moderate to high level of physical load.

Boyle et al (1994) found a similar HR response when studying the work rates of international hockey representative players in Ireland despite the subject characteristics being substantially different to those of Ghosh et al (1991). Players were taller, heavier and had higher VO$_2$max than those of the Indian sample group. HR was recorded at 5 second intervals during club competition and referenced to HR’s measured during a laboratory test of maximum oxygen consumption. Mean HR during match play was 158.6 ± 8 b.min$^{-1}$ and average oxygen consumption was estimated as 77.9%±7.3 VO$_2$max. However only nine subjects were monitored (one player per game for nine games) and no individual playing position had two sets of data.

Johnston et al (2004) only reported the findings from single measurements on 15 elite male hockey players in the Scottish National
League. One player was filmed per match for 15 weeks consisting of five defenders, five midfielders and five attackers. Using the video footage, activities were subjectively categorized as standing, walking, jogging, striding and sprinting so as to establish work to rest ratios and profiles of match play. Players spent the majority of time stationary (4.0%) or engaged in low intensity activity (walking 50.9%, jogging 29.6%) with only a small portion of the match in high intensity activity (cruising 10.1%, sprinting 4.7%). Mean HR was 155 ± 12 b.min⁻¹ and players spent 64% of match time above 75% of HRmax. The mean ratio of high intensity (cruising and sprinting) to low intensity (standing, walking, jogging) activity was 1:5.7 ± 0.6 with minimal positional differences. Players performed 30 ± 6 sprints with an average sprint duration of 5.7 seconds. This is the first published study to describe the temporal characteristics of hockey and although the calibre of the matches was only moderate, the information provides a useful categorization of the time spent in different locomotion categories. They found that the overwhelming proportion of time was spent either stationary, walking or jogging suggests that the game consists of short bursts of high intensity work superimposed onto an aerobic framework. They additionally found that players on average performed 30 sprints of 5.7 seconds per match indicate that the ability to perform and recover rapidly from high intensity activity is a key physical quality for elite hockey players.

Findings from a higher level of competition were reported by Spencer et al (2004) who used video analysis to monitor the activities of the
Australian Men’s team during an international match. While watching video playback the researchers subjectively identified and placed player motions into categories of standing, walking, jogging, striding and sprinting using the locomotion criteria of Bangsbo et al (1991). The mean match time of each player was 48 minutes with only three players being involved for the entire 70-minute duration. Low intensity activities of standing walking and jogging accounted for approximately 94% of match time (7.4% standing, 46.5% walking, 40.5% jogging). Only 5.6% of match time was spent performing high intensity running which compares favourably with the findings of Boyle et al and suggests little difference between the proportion of time spent in intensity categories at international level as compared to elite domestic level. Notable position differences were reported with respect to high intensity activity with inside forwards and strikers performing more sprints than fullbacks and halfbacks. The motions of all players were grouped into a team motion category and the flow of this motion was assessed during 5 minute periods throughout the match. It was reported that as a half-progressed there were increases in the amount of standing and walking that occurred. For example, compared with the initial 5 minute period in the second half, the subsequent 30 minutes saw a significant increase in percent time spent walking and standing and a significant decrease in percent time jogging. Mean sprint duration was 1.8 seconds with an average of 30 ± 12 sprints per player. Although the number of sprints recorded per player per game is identical to that reported by Johnston et al (2004) the sprint duration is
substantially lower (1.8s v 5.7s) which is likely due to different criteria used to log the start time of the sprint. Using typical speed testing data from an elite population, an average sprint of 5.7s suggests a distance of 40-50m per effort. Such a sprint duration is rare during hockey match play (Lythe, 2006) with average sprint durations of 1-3 seconds being much more typical of time-motion studies of team sports so the findings of Spencer et al (2004) seem to be more realistic.

Jennings, et al., (2012) compared the activity profile of national and international male field hockey athletes. Sixteen players (mean (±SD) age, stature, and body mass: 22 ± 4 y, 178 ± 8 cm, and 78 ± 9 kg, respectively) competing in the national-level Australian Hockey League (AHL) and 16 players [mean (±SD) age, stature, and body mass: 27 ± 4 y, 179 ± 5 cm, and 77 ± 5 kg, respectively] competing in the international Champions Trophy (CT) tournament participated in this study. Global positioning systems assessed total distance (TD), meters per minute (m·min(-1)), and high-speed running distance (HSR; >4.17 m·s(-1)). Differences in multistage fitness test performance, movement between competition, positions, and halves were assessed using effect size and percent difference ±90% confidence intervals. The CT players had a 10.1% greater multistage fitness test, 13.9% and 42.0% more TD and HSR, respectively, than AHL. During CT, strikers performed 10.1 ± 7.4% less HSR than midfielders and 26.6 ± 8.2% more HSR than defenders. The AHL defenders covered less TD and HSR distance compared with strikers and midfielders (8.1 ± 3.6% and 8.4 ± 2.6%; 36.1 ± 11.1% and
51.5 ± 12.1%, respectively). The AHL strikers, midfielders, and defenders (19.9 ± 8.8%, 32.1 ± 7.9%, and 30.3 ± 10.7%, respectively), all performed less HSR distance than their CT counterparts. Finally, TD decreased from the first to second halves across all positions (6.1-7.5%) in both competitions. International competition increases the running profile of hockey players, with greater HSR at the elite level and positional differences including decreased running during the second half in both competitions.

Wassmer and Mookerjee (2002) developed a descriptive profile and examined the relationships between grip strength, power and sport specific test performance in 37 elite, female collegiate field hockey players (N=8 backs, N=13 forwards, N=4 goalkeepers, N=8 midfield players, N=4 wings). The tests included circumference and limb lengths, %body fat, Margaria-Kalamen stair test, 50-yard dash test, Queen's College step test, grip strength, Illinois agility test, field hockey specific skills tests, and a coordination test.

The mean (+/-SD) height, weight, percent body fat, and predicted oxygen consumption were 164.26 (+/-5.17) cm, 63.06 (+/-8.60) kg, 17.29 (+/-3.79)% and 42.87 (+/-9.08) ml x kg(-1) x min(-1), respectively. Although the goalkeepers were significantly (p<0.05) heavier and had a higher %body fat, there were no significant differences (p>0.05) between any of the player positions in height, limb length, 50-yard dash time, predicted VO2max, grip strength, agility, or in the field hockey specific tests. There were no significant (p>0.05) correlations (r=0.03 to -0.13) between right and left grip strength and sport-specific test scores but significant (p<0.05) relationships
were found between power and pushing accuracy, as well as between the 50 yard dash and coordination test, pushing power and pushing accuracy. They concluded that there are similarities amongst the defensive and offensive players with international level field hockey players, and those measures of power and sport specific tests are significantly correlated.

Popadic Gacesa, et al., (2009) investigated the values of anaerobic energetic capacity variables in athletes engaged in different sport disciplines and to compare them in relation to specific demands of each sport. Wingate anaerobic tests were conducted on 145 elite athletes (14 boxers, 17 wrestlers, 27 hockey players, 23 volleyball players, 20 handball players, 25 basketball players, and 19 soccer players). Three variables were measured as markers of anaerobic capacity: peak power, mean power, and explosive power. The highest values of peak power were measured in volleyball 11.71 +/- 1.56 W.kg and basketball players 10.69 +/- 1.67 W.kg, and the difference was significant compared with the other athletes (p <= 0.05). The lowest value of peak power (8.58 +/- 1.56 W.kg) was registered in handball players. The mean power variable showed a similar distribution as peak power among groups. The highest values of explosive power were also registered in volleyball 1.75 +/- 0.33 W.s.kg and basketball players 1.64 +/- 0.35 W.s.kg, but there was no significant difference in values between volleyball players and wrestlers, between boxers and wrestlers, between boxers and basketball players, and between volleyball and hockey players (p > 0.05). The measured results show the influence of anaerobic capacity in different sports and the
referral values of these variables for the elite male athletes. Explosive power presented a new dimension of anaerobic power, i.e., how fast maximal energy for power development can be obtained, and its values are high in all sports activities that demand explosiveness and fast maximal energy production. Coaches or other experts in the field could, in the future, find useful to follow and improve, through training process, one of the variables that is most informative for that sport.

Keogh, et al., (2003) developed an effective testing battery for female field hockey by using anthropometric, physiological, and skill-related tests to distinguish between regional representative (Rep, n = 35) and local club level (Club, n = 39) female field hockey players. Rep players were significantly leaner and recorded faster times for the 10-m and 40-m sprints as well as the Illinois Agility Run (with and without dribbling a hockey ball). Rep players also had greater aerobic and lower body muscular power and were more accurate in the shooting accuracy test, p < 0.05. No significant differences between groups were evident for height, body mass, speed decrement in 6 x 40-m repeated sprints, handgrip strength, or pushing speed. Their results indicated that %BF, sprinting speed, agility, dribbling control, aerobic and muscular power, and shooting accuracy can distinguish between female field hockey players of varying standards. Therefore talent identification programs for female field hockey should include assessments of these physical parameters.
Scott (1991) established a data base of physical norms for elite male field hockey players. Direct measurements were made on eight parameters and a further three derived variables were calculated. With a stature of 176.3 cm and mass of 75.2 kg the hockey players were identified as ecto-mesomorphic. The lean build of the subjects was evident with a fairly low percentage body fat (11.1%) and a relatively high RPI of 41.77. Functional arm length did not appear to have any correlation with hockey playing ability. However, grip strength, in both right (54.0 kg) and left (53.1 kg) measures was above that of norms for male adults and there was no significant difference between left and right grip strength. The players appeared to have good leg strength (stand long jump mean 2.3 m) with very little variability amongst the players. On the other hand flexibility (sit and reach mean 9.7) was poor and results indicated a wide range of variability in the sample group tested.

Boyle, et al., (1994) established the energy cost of competitive field hockey, for which nine international hockey players wore a modified Sport Tester PE3000 telemetric heart rate monitor during match play and also completed a laboratory based incremental treadmill test to establish maximal oxygen uptake (VO$_2$max). The heart rate data from competition were compared with heart rate and oxygen uptake data measured in the laboratory. Individual regression equations were established from these data to estimate the energy expenditure during competitive match-play. The mean heart rate during competition was 159 ± 8 beats/min (mean ± SD). The mean estimated
oxygen uptake during competition was 48.2 ± 5.2 ml/kg/min which is commensurate with 78% of the group's mean maximal oxygen uptake of 61.8 ± 1.8 ml/kg/min. The mean estimated energy expenditure throughout an entire match was 5.19 MJ and rates of energy expenditure ranged from 83 kJ/min for the centre midfield position to 61.1 kJ/min for the left corner forward position. Their study has shown the feasibility of heart rate monitoring as a means of estimating energy expenditure in elite hockey. Competitive matches place a heavy demand on the aerobic system and require players to expend energy at relatively high levels.

Macleod and Sunderland (2012) assessed the reliability of the physiological and metabolic responses to a sport-specific treadmill protocol designed to simulate the activity pattern of elite women's field hockey match-play. To fulfill the purpose eight elite female field hockey players completed two trials of the Field Hockey Intermittent Treadmill Protocol (FHITP) separated by 5 days. The protocol consisted of 50 min of intermittent treadmill running designed to replicate the demands of match-play. Heart rate was determined continuously using Polar Team monitors. Rectal temperature was recorded every 10 min and capillary blood samples were taken at rest, at half-time (immediately after the completion of the first half) and at the end of the protocol for analysis of blood glucose and lactate. Their result showed that heart rate response (CV 3.5%, CI, 2.9% to 4.4%), rectal temperature (CV 0.6%, 95% CI, 0.5% to 0.8%) and blood glucose (CV 1.4%, 95% CI, 1.1% to 2.1%) were all reproducible. No systematic error was evident between trials
for blood lactate response (P=0.289) to the FHITP, although the overall CV for the measurement was 14.2% (95% CI, 10.7% to 21.2%). They concluded that the physiological and metabolic responses to the FHITP were highly reproducible with the recommendation that blood lactate concentrations are used in conjunction with heart rate or other key performance measures to assess performance.

**Seasonal variations in physical fitness variables of hockey players**

Manna, Khanna and Dhara, (2009) analysed the training induced changes on different physiological and biochemical parameters in young Indian field hockey players. A total of 30 Indian male field hockey players (age range 14-16 yrs) regularly playing competitive field hockey were selected; a training programme consist of aerobic and anaerobic exercise were followed for 6 wks and 12 wks respectively. Results showed a significant decrease (P<0.05) in body fat, and a significant increase (P<0.05) in LBM following both 6 wks and 12 wks of training. Strength of backs and handgrip muscles were also increased significantly (P<0.05) after the training. Significant reduction (P<0.05) in heart rates during sub-maximal exercises, maximal exercises and recoveries were noted after both the training programme. Moreover, significant increase (P<0.05) in aerobic capacity and anaerobic power were observed after the training. Further, significant reductions (P<0.05) were noted in hemoglobin, total cholesterol, triglyceride and LDLC after the training. On the other hand plasma levels of urea, uric acid and HDLC were increased significantly (P<0.05) following the training.
Their study showed a decrease in body fat and the plasma levels of cholesterol as well as LDLC and increase in HDLC, which is beneficial for good health and better performance. However, reduction in hemoglobin and increase in plasma urea and uric acid may be due to increased training load. Since the data on field hockey players are limited in India, therefore their study may provide useful information to the coaches to develop their training programme.

Granados, et al., (2008) selected sixteen elite female handball players and examined the effects of an entire season on anthropometric characteristics, physical fitness, and throwing velocity. One-repetition-maximum bench press (1RMBP), jumping explosive strength, power-load relationship of the leg and arm extensor muscles, 5- and 15-m sprint running time, endurance running, and handball throwing velocity were assessed in four periods. Individual volumes and intensities of training and competition were quantified for 11 activities. The result of the study showed that during the season, significant increases (P < 0.05-0.01) occurred in fat-free mass (1.8 +/- 1.2%), 1RMBP (11 +/- 7.4%), bench press (12-21%) and half-squat (7-13%) muscle power output, vertical jumping height (12 +/- 7.2%), throwing velocity (8 +/- 5.9%), and a significant decrease in percent body fat (9 +/- 8.7%). No changes were observed in sprint and endurance running. Significant correlations (P < 0.05-0.01) were observed between time devoted to games and changes in velocity at submaximal loads during bench press actions, as well as between changes in muscle velocity output of the upper
and lower extremities and changes in throwing velocity. Changes in percent body fat or body mass correlated ($P < 0.01$) positively with changes in maximal strength and muscle power. They concluded that handball season resulted in significant increases in anthropometric characteristics, physical fitness, and throwing velocity. The correlations observed suggested the importance of including explosive strength exercises of the knee and elbow extensions. Special attention may be needed to be paid to the mode of body fat loss, to increase endurance capacity without interfering in strength gains. Official and training games may be an adequate stimulus for enhancing certain physical fitness characteristics in female elite handball players.

Gorostiaga, et al., (2006) selected fifteen elite male handball players and examined the effects of an entire season of play on physical fitness and throwing velocity. One repetition maximal bench press (1RMBP), jumping explosive strength, power-load relationship of the leg and arm extensor muscles, 5- and 15-m sprint running time, endurance running, and handball throwing velocity (standing and three-step running throw) were assessed on four times (T1, T2, T3, and T4), during a 45-wk season. Individual volumes and intensities of training and competition were quantified for 11 activities. The result of the study showed that from T1 to T3, significant increases occurred in free fatty mass (1.4%), 1RMBP (1.9%), standing throwing velocity (6.5%), and three-step throwing velocity (6.2%). No significant changes were observed throughout the season in endurance running and explosive strength-related variables. Significant correlations ($P < 0.05$-$0.01$)
were observed between strength training time and changes in standing throwing velocity as well as between high-intensity endurance training time and changes in endurance running. In addition, linear inverse relationships were observed between low-intensity endurance training time and changes in muscle power output of the lower extremities. They concluded that handball season resulted in significant increases in maximal and specific strength of the upper-extremity but not in the lower-extremity actions. The correlations observed suggested that training time at low intensity should be given less attention, whereas the training stimuli for high-intensity endurance running and leg strength training should be given more careful attention in the full training season program.

Koutedakis (1995) stated that in many sports, training for successful competition has become virtually a year-round endeavor. To assist in better preparation, a competitor's year may be divided into phases such as off-season and in-season, indicating reduced or increased competition commitments, respectively. A number of studies have described the effects of seasons or periods of competition, training, detraining and reduced training on aspects of physical fitness. Depending on performance level, the type of sport and the fitness parameter in question, the swings in fitness variables reported may be as high as 18% from one season to another. In elite competitors, anaerobic parameters, heart frequencies, subcutaneous fat, flexibility and hemoglobin levels remain relatively unchanged throughout the year. Aerobic metabolism and muscular strength may demonstrate noticeable (mostly unfavourable)
changes, and plasma hormonal levels normally follow changes in training intensities. Aspects related to long term fatigue and genetics, and to appropriate training are just a few explanations for these observations. It is still not known whether greater fitness gains attainable with longer off-season training programmes can be successfully maintained over the duration of the competition season. However, the consensus would seem to be that specialised training (based on technique and competition tactics only) is inadequate for fitness maintenance and/or improvements. This is perhaps supported by the general trends found in the literature regarding muscular strength: while supervised off-season conditioning programmes may result in significant improvements for both recreational and competitive athletes, no such changes are normally observed after competition seasons. These findings may reflect, amongst other factors, a lack of optimal training intensity to bring about strength increases during in-season periods. In novices and in athletes at low competitive levels, training seasons may lead to considerable functional improvements of the cardiorespiratory system, coupled with occasional increases in muscular strength and decreases in body fat. Relatively low fitness levels at the beginning of training have been put forward as an explanation for these improvements. Seasons of training and competition result in no significant changes in flexibility measurements. Similar changes to those found in novices and in athletes at low competitive levels may also be seen in children and adolescents engaged in sport, although their fitness improvements are consistent with normal patterns of growth and
development. No differences have been identified between male and female athletes participating at different competition levels.

Gabbett (2005) investigated the physiological and anthropometric characteristics of junior rugby league players over a competitive season. Forty-five rugby league players were allocated into training (n = 36) and nonexercise control (n = 9) groups. The training group participated in 2 field-training sessions each week with training loads, match loads, and injury rates recorded. Subjects performed measurements of standard anthropometry (height, body mass, and sum of 7 skinfolds), muscular power (vertical jump), speed (10-, 20-, and 40-m sprint), agility ('L run'), and estimated maximal aerobic power (multi-stage fitness test) in December (off-season), March (preseason), May (midseason), and August (end-season). Training loads progressively increased in the general preparatory phase of the season (preseason period), and declined slightly during the competitive phase of the season. Match intensity and match loads decreased throughout the season. Increases in estimated maximal aerobic power and muscular power and reductions in skinfold thickness occurred during the general preparatory phase of the season, and were maintained throughout the competitive phase of the season. Their findings suggested that high training loads in the general preparatory phase of the season and low match loads in the competitive phase of the season allow junior rugby league players to maintain a high level of fitness throughout an entire competitive season.
Gabbett (2005) investigated the physiological and anthropometric characteristics of rugby league players during a competitive season. Sixty-eight rugby league players were allocated into training (n = 52) and nonexercise control (n = 16) groups. The training group participated in 2 field-training sessions per week, with training loads, match loads, and injury rates recorded. Subjects performed measurements of standard anthropometry (height, body mass, and sum of 7 skinfolds), muscular power (vertical jump), speed (10-, 20-, and 40-m sprint), agility (L run), and maximal aerobic power (multistage fitness test) in December (off-season), March (preseason), May (midseason), and August (end season). Increases in maximal aerobic power and muscular power and reductions in skinfold thickness were observed during the early phases of the season when training loads were highest. However, reductions in muscular power and maximal aerobic power and increases in skinfold thickness occurred toward the end of the season, when training loads were lowest and match loads and injury rates were highest. Their findings suggested that high overall playing intensity and match loads in end-season matches increase in injury rates in the latter half of the season, and residual fatigue associated with limited recovery between successive matches may compromise the physical development of rugby league players.

López-Segovia, et al., (2010) assessed the effect of the training executed by 2 under-19 teams from the first Spanish division on aerobic power, strength, and acceleration capacity. Two under-19 soccer teams that competed in the same league were evaluated on 2 occasions. The first
evaluation ($E_1$) was done at the beginning of the competitive period, and the second evaluation ($E_2$) was done 16 weeks later, coinciding with the end of the first half of the regular season. The following were evaluated: lower-body strength through jump height with countermovement with and without load (CMJ/CMJ$_{20}$), speed of the Smith machine bar movement in a progressive load test of full squats (FSL), acceleration capacity in 10, 20, and 30 m ($T_{10}$, $T_{20}$, $T_{30}$, $T_{10-20}$, $T_{10-30}$, $T_{20-30}$), and maximal aerobic speed (MAS). Team A executed complementary strength training, and training loads were determined with regard to the speed with which each player moved the bar in FSL. Between the evaluations, the training sessions of each team were recorded to assess their influence on the changes in $E_2$. Team A significantly improved its MAS ($p < 0.01$) and its application of strength in the CMJ$_{20}$ ($p < 0.05$) and FS$_{20-30-40}$ ($p < 0.01$), while significantly worsening their acceleration capacity in all the splits ($p < 0.01$). Team B slightly worsened its MAS and significantly improved its application of strength in the CMJ$_{20}$ ($p < 0.01$) and FS$_{50-60}$ ($p < 0.05$). Its acceleration capacity improved insignificantly except for in the 20- to 30-m interval/T$_{20-30}$ ($p < 0.05$). Their study demonstrated that the use of loads as a function of the speed of movement, without the need to determine maximum repetitions is a methodology that is adequate for the improvement of the application of strength in under-19 soccer players.

Nimphius, McGuigan and Newton (2012) broadly classified their purpose into two folds as: (a) to examine the performance changes that occur
in elite female softball players during 20 weeks of softball training (that included 14 weeks of periodized resistance training [RT]) and (b) to examine the relationship between percent change (%change) in muscle architecture variables and %change in strength, speed, and change of direction performance. Ten female softball players (age = 18.1 ± 1.6 years, height = 166.5 ± 8.9 cm, weight = 72.4 ± 10.8 kg) from a state Australian Institute of Sport softball team were tested for maximal lower-body strength using a 3 repetition maximum for a predicted 1 repetition maximum (1RM) and peak force, peak velocity (PV), and peak power (PP) were measured during jump squats (JS) unloaded and loaded. In addition, the first base (1B) and the second base (2B) sprint performance change of direction (505) on dominant (D) and nondominant (ND) sides, aerobic capacity, and muscle architecture characteristics of vastus lateralis (VL) including muscle thickness (MT), fascicle length (FL), and pennation angle (θp) were examined. The testing sessions occurred during pre, mid, and post training (total 20 week pre- and in-season training period). Changes over time were analyzed by repeated-measures analysis of variance. The relationship between %change in muscle architecture variables and strength, speed, and change of direction variables from pre to post were assessed by Pearson product-moment correlation coefficient. Significant improvements in PV and PP occurred at all JS loads pre- to mid-testing and pre- to post-testing. Significant increases occurred pre-post in absolute 1RM, relative 1RM, 505 ND, and 2B sprint. The strongest relationships were found between %change in VL MT and 1B sprint (r = -
0.80, p = 0.06), %change in VL FL and 2B sprint (r = -0.835, p = 0.02), and %change in relative 1RM and 505 D (r = -0.70, p = 0.04). They found that gains in strength, power, and performance can occur during the season in elite softball players who are also engaged in a periodized RT program. Furthermore, changes in performance measures are associated with changes in muscle architecture.

Argus, et al., (2012) compared the effects of two contrast training programs on a range of measures in high-level rugby union players during the competition season. Their programs consisted of a higher volume-load (strength-power) or lower volume-load (speed-power) resistance training; each included a tapering of loading (higher force early in the week, higher velocity later in the week) and was performed twice a week for 4 wk. Eighteen players were assessed for peak power during a bodyweight countermovement jump (BWCMJ), bodyweight squat jump (BWSJ), 50 kg countermovement jump (50CMJ), 50 kg squat jump (50SJ), broad jump (BJ), and reactive strength index (RSI; jump height divided by contact time during a depth jump). Players were then randomized to either training group and were reassessed following the intervention. Inferences were based on uncertainty in outcomes relative to thresholds for standardized changes. The result of the study showed that there were small between-group differences in favor of strength-power training for mean changes in the 50CMJ (8%; 90% confidence limits, ±8%), 50SJ (8%; ±10%), and BJ (2%; ±3%). Differences between groups for BWCMJ, BWSJ, and reactive strength index were unclear. For
most measures there were smaller individual differences in changes with strength-power training. They concluded that high-level rugby union athletes should be exposed to higher volume-load contrast training which included one heavy lifting session each week for larger and more uniform adaptation to occur in explosive power throughout a competitive phase of the season.

Farzad, et al., (2011) examined the effects of 4 weeks of sprint-interval training (SIT) program, on selected aerobic and anaerobic performance indices, and hormonal and hematological adaptations, when added to the traditional Iranian training of wrestlers in their preseason phase. Fifteen trained wrestlers were assigned to either an experimental (EXP) or a control (CON) group. Both groups followed a traditional preparation phase consisting of learning and drilling technique, live wrestling and weight training for 4 weeks. In addition, the EXP group performed a running-based SIT protocol. The SIT consisted of 6 35-m sprints at maximum effort with a 10-second recovery between each sprint. The SIT protocol was performed in 2 sessions per week, for the 4 weeks of the study. Before and after the 4-week training program, pre and posttesting was performed on each subject on the following: a graded exercise test (GXT) to determine VO\(_2\)max, the velocity associated with V\(_2\)max (vVO\(_2\)max), maximal ventilation, and peak oxygen pulse; a time to exhaustion test (T\(_{max}\)) at their vVO\(_2\)max; and 4 successive Wingate tests with a 4-minute recovery between each trial for the determination of peak and mean power output (PPO, MPO). Resting blood samples were also collected at the beginning of each pre and posttesting period, before and after the 4-
week training program. The EXP group showed significant improvements in VO$_2$max (+5.4%), peak oxygen pulse (+7.7%) and T$_{max}$ (+32.2%) compared with pretesting. The EXP group produced significant increases in PPO and MPO during the Wingate testing compared with pretesting (p < 0.05). After the 4-week training program, total testosterone and the total testosterone/cortisol ratio increased significantly in the EXP group, whereas cortisol tended to decrease (p = 0.06). Their findings indicated that the addition of an SIT program with short recovery can improve both aerobic and anaerobic performances in trained wrestlers during the preseason phase. The hormonal changes seen suggested training-induced anabolic adaptations.

Gabbett and Domrow (2007) developed a statistical model that estimate the influence of training load on training injury and physical fitness in collision sport athletes. The incidence of training injuries was studied in 183 rugby league players over two competitive seasons. Participants were assessed for height, body mass, skinfold thickness, vertical jump, 10-m, 20-m and 40-m sprint time, agility, and estimated maximal aerobic power in the off-season, pre-season, mid-season, and end-season. Training load and injury data were summarised into pre-season, early-competition, and late-competition training phases. Individual training load, fitness, and injury data were modelled using a logistic regression model with a binomial distribution and logit link function, while team training load and injury data were modelled using a linear regression model. While physical fitness improved with training, there was no association (P=0.16-0.99) between training load and
changes in physical fitness during any of the training phases. However, increases in training load during the early-competition training phase decreased (P= 0.04) agility performance. A relationship (P= 0.01-0.04) was observed between the log of training load and odds of injury during each training phase, resulting in a 1.50 - 2.85 increase in the odds of injury for each arbitrary unit increase in training load. Furthermore, during the pre-season training phase there was a relationship (P= 0.01) between training load and injury incidence within the training load range of 155 and 590 arbitrary units. During the early and late-competition training phases, increases in training load of 175-620 arbitrary units and 145-410 arbitrary units, respectively, resulted in no further increase in injury incidence. Their findings demonstrated that increases in training load, particularly during the pre-season training phase, increase the odds of injury in collision sport athletes. However, while increases in training load from 175 to 620 arbitrary units during the early-competition training phase result in no further increase in injury incidence, marked reductions in agility performances can occur. Their findings suggested that reductions in training load during the early-competition training phase can reduce the odds of injury without compromising agility performances in collision sport athletes.

Paton and Hopkins (2005) reported the seasonal changes and variability in power of 12 male competitive cyclists, who performed laboratory tests of incremental peak and 4-km mean power measured with three ergometers simultaneously in each of five sessions during three phases
(base, pre-comp, comp) of a season. Repeated-measures analysis of log-transformed power provided mean percent changes in performance between phases and within-cyclist variability in performance expressed as coefficients of variation between sessions < or = 2 wk apart within a phase and between sessions 8 wk-12 wk apart in different phases. Peak power increased from the base phase to the pre-comp phase on average by 5.3%, and by a further 1.8% from pre-comp to comp phase; corresponding increases in 4-km mean power were 6.1% and 2.2% (90% likely limits all approximately +/-2.6%). The variabilities for peak and 4-km mean powers were 1.2%-1.8% for sessions separated by < or = 2 wk and 2.0%-2.3% for sessions in pre-comp and comp phases, but increased to 3.4%-3.8% for sessions between the base and other phases. Individual differences in the improvement in performance after the base phase evidently produced the greater variability between the base and the other phases. Interventions that might produce small but worthwhile changes in performance over a period of weeks-months need to be researched in pre-comp and comp phases, when the variability is small.

Gastin, et al., (2012) investigated the influence of player characteristics (physical fitness, age, and playing experience) and weekly in-season training load on elite match performance across an Australian football season. Twenty-five players (age: 24.1 ± 3.0 y; height: 188.3 ± 7.3 cm; weight: 90.4 ± 8.3 kg) from one elite team participated in this study. Prior to the season, player's age, experience, height and weight along with measures of aerobic (6 min run) and anaerobic (6 x 40 m repeated sprints) physical fitness were
recorded. Individual player training load during the season was measured using GPS technology for the main training session of the week. Player match performance was calculated weekly from 33 individual playing statistics. Multi-level modelling was used to investigate the relationship between weekly training load and match performance and to explore the influence of player characteristics on this relationship. Playing experience ($p < 0.01$) and aerobic fitness ($p < 0.05$) displayed positive relationships with performance while player age ($p < 0.01$) showed a negative relationship. Most players coped well with weekly variations in training load; however the relationship was moderated by the results of the pre-season repeated sprint test ($p < 0.05$). The adverse effect on playing performance in selected players following a more intense training session suggested that recovery from the session may be delayed in players who exhibit a better anaerobic fitness profile.

Mikulic (2012) examined variations in physical, physiological, and performance parameters over an annual training cycle in a world champion rowing crew. To achieve purpose four world-class rowers, all of them members of the men's heavyweight quadruple sculls squad who are current world rowing champions, were assessed 3 times at regular 4-mo intervals during the 2011 season (November 2010, March 2011, and July 2011). Physical assessments included stature, body mass, body composition, whereas physiological and performance assessments obtained during an incremental rowing ergometer test to exhaustion included maximum oxygen uptake and anaerobic gas-exchange threshold with corresponding power output values.
The result of the study showed that body mass (95 kg) and body composition (12% body fat) remained stable over the annual training cycle. Power output at anaerobic gas-exchange threshold increased +16% from November to July, whereas the corresponding oxygen uptake, expressed as a percentage of maximum oxygen uptake, increased from 83% to 90%. Maximum oxygen uptake decreased from 6.68 L/min in November to 6.10 L/min in March before rising to 6.51 L/min in July. The corresponding power output increased steadily from 450 W to 481 W. They concluded that seasonal variation in body mass and body composition of 4 examined world-class rowers was minimal. Oxygen uptake and power output corresponding to anaerobic threshold continuously increased from off-season to peak competition season. Seasonal variation in maximum oxygen uptake reached 10%; however, it remained above 6 L/min, that is, the value consistently observed in top caliber heavyweight rowers regardless of the time of the assessment.

Caldwell and Peters (2009) investigated seasonal variations in physiological fitness of semiprofessional soccer players over a 12-month period. Thirteen male players were tested 5 times over a 12-month period using bioelectrical impedance, a 20-m multistage fitness test, countermovement standing vertical jump, 15-m sprint test, Illinois agility test, and sit and reach test. Significant deconditioning was apparent in all fitness variables from end of season one season to prepreseason training of the next season. Aerobic fitness, vertical jump, percent body fat, agility, and sprint performance improved from prepreseason to midseason. Significant decreases
in aerobic fitness and the cessation of significant increases in vertical jump, sprint, and agility performance were shown from midseason onward. No differences between the fitness components at the end of season one and the end of season two were identified. The deconditioning apparent in all fitness parameters during the off season, together with progressive improvement in most from postseason to midseason would support these parameters as sport-specific fitness requirements. Such improvements suggested that the short-term demands of playing and training in the first half of the season develop fitness and these trends are similar to those for professional players. Body fat was also shown to be detrimental to sprint performance throughout the 12-month period. Further research is needed to identify if the plateau in fitness from midseason is the result of attaining the required level of fitness, fatigue, allied training, or even relative success. Enhancing off-season training may enable yearly fitness increases by at least maintaining fitness levels for the next year's preseason.

Kyriazis, et al., (2009) investigated changes in shot put performance, muscular power, and neuromuscular activation of the lower extremities, between the preseason and the competition period, in skilled shot put athletes using the rotational technique. Shot put performance was assessed at the start of the pre-season period as well as after 12 weeks, at the competition period, in nine shot putters. Electromyographic (EMG) activity of the right vastus lateralis muscle was recorded during all shot put trials. Maximum squat strength (1RM) and mechanical parameters during the countermovement
jump (CMJ) on a force platform were also determined at pre-season and at competition period. Shot put performance increased 4.7% ($p < 0.05$), while 1RM squat increased 6.5% ($p < 0.025$). EMG activity during the delivery phase was increased significantly ($p < 0.025$) after the training period. Shot put performance was significantly related with muscular power and takeoff velocity during the CMJ, at competition period ($r = 0.66$, $p < 0.05$ and $0.70$, $p < 0.05$), but not with maximum vertical force. One RM squat was not related significantly with shot put performance. Their results suggested that muscular power of the lower extremities is a better predictor of rotational shot put performance than absolute muscular strength in skilled athletes, at least during the competition period.

Magal, et al., (2009) examined changes in various aerobic and anaerobic physical performance measures in male National Collegiate Athletic Association (NCAA) Division III soccer players during the competitive soccer season. Twelve starters of the men's soccer team ($mean +/- SD$; age = 20.0 +/- 0.9 years, height = 175.7 +/- 8.1 cm, body mass = 73.9 +/- 11.00 kg, body mass index [BMI] 24.0 +/- 3.0 kg.m2, and percent body fat = 10.6 +/- 5.4%) were tested at the beginning (PRS) and the end (POS) of the collegiate soccer season. Each experimental trial included a maximal aerobic capacity test ($VO_2$ max); 10-, 30-, and 40-m sprints; pro-agility test; and the Wingate anaerobic power test (WAnT). From PRS to POS, $VO_2$ max significantly increased (51.05 +/- 5.97 vs. 54.64 +/- 4.90 ml/kg/min), and the 10- and 30-m sprint were significantly lower (2.03 +/-
0.15 vs. 1.96 +/- 0.11 seconds and 4.72 +/- 0.26 vs. 4.51 +/- 0.24 seconds, respectively). Anthropometric measures, 40-m sprint, pro-agility test, and WAnT were not significantly different between PRS and POS. The results of their study indicated that NCAA Division III male soccer players appear to improve aerobic and anaerobic performance measures during the competitive soccer season. It is arguable that these performance improvements may represent a poor preseason conditioning level that may result in a competitive disadvantage during the early stages of the season.

There are different football codes played around the world, and most of them involve contact and collision during competition. Upper-body strength and power are important for success in American football, rugby league, rugby union, and Australian football. The goal of the preseason conditioning program is usually to maximize muscular fitness before the competitive season. The in-season program is usually intended to maintain the preseason gains, but it is unclear as to whether the preseason levels of upper-body strength and power can be maintained or even increased during the in-season. Hrysomallis (2010) review aimed to investigate and identify any general trends in the training programs and results of football studies that have monitored levels of upper-body strength and power preseason, in-season, or postseason. Six studies were identified: 4 involved American college football and the other 2 involved rugby codes and included professional athletes. For most studies, resistance training was conducted 4 times per week preseason and reduced to 2 times per week in-season. The bench press exercise was used
as the measure of upper-body strength, and only one of the rugby studies measured upper-body power and used bench press throws. They found that upper-body strength or power could be maintained or even increased past the mid-season point, but this may be dependent on age, football code, and level of play. At the end of the season, decreases were starting to be reported but only for 2 studies. Surprisingly, an increase in strength was reported postseason for college rugby league players. From the available information, they suggested that an in-season periodized program that includes high-intensity resistance training may optimize strength and power ability during the in-season, but more research is required that compares the effectiveness of conditioning programs with varying combinations of training variables.

Miller, et al., (2011) developed a profile of soccer-related fitness parameters on elite National Collegiate Athletic Association (NCAA) Division III male soccer players during the off-season. Sixteen underclassmen from a recent NCAA Division III national championship soccer team completed a series of tests across 3 separate occasions over a 15-day period, with adequate recovery time between sessions to eliminate any carryover effect. Physiological parameters measured included aerobic endurance, anaerobic power and capacity, jumping power, agility, hamstring flexibility, and body composition. Descriptive statistics such as the mean (±SD) and range were calculated for each test. Two-tailed Pearson correlations were run to determine significant relationships that existed between variables. Test results were T-Tests (9.9 ± 0.4), Active Knee Extension degrees (-34.2 ± 11.9
right, -34.0 ± 13.9 left), vertical jump (61.8 ± 7.2 cm), percent fat (5.6 ± 1.6), Progressive Aerobic Cardiovascular Endurance Run (PACER) laps (113.2 ± 12.3), estimated VO$_2$max (53.6 ± 2.9 ml/kg/min), Wingate peak (802.7 ± 155.6 W), Wingate peak (10.9 ± 1.2 W/kg), Wingate mean (651.2 ± 101.6 W), Wingate mean (8.9 ± 0.6 W/kg), and Wingate fatigue rate (35.9 ± 8.4%).

Strong correlations existed between PACER laps and percent fat, between peak W and peak W/kg, and between peak W and fatigue rate. Their results suggested that elite Division III soccer players maintain relatively high fitness levels during the off-season. Additionally, they provided coaches with preliminary norms that can be used to determine off-season training expectations and adjust programs accordingly for their athletes.

Issurin (2010) stated the theory of training was established about five decades ago when knowledge of athletes' preparation was far from complete and the biological background was based on a relatively small amount of objective research findings. At that time, traditional 'training periodization', a division of the entire seasonal programme into smaller periods and training units, was proposed and elucidated. Since then, international sport and sport science have experienced tremendous changes, while the traditional training periodization has remained at more or less the same level as the published studies of the initial publications. As one of the most practically oriented components of theory, training periodization is intended to offer coaches basic guidelines for structuring and planning training. However, during recent decades contradictions between the traditional model of periodization and the
demands of high-performance sport practice have inevitably developed. The main limitations of traditional periodization stemmed from: (i) conflicting physiological responses produced by 'mixed' training directed at many athletic abilities; (ii) excessive fatigue elicited by prolonged periods of multi-targeted training; (iii) insufficient training stimulation induced by workloads of medium and low concentration typical of 'mixed' training; and (iv) the inability to provide multi-peak performances over the season. The attempts to overcome these limitations led to development of alternative periodization concepts. The recently developed block periodization model offers an alternative revamped approach for planning the training of high-performance athletes. Its general idea proposes the sequencing of specialized training cycles, i.e. blocks, which contain highly concentrated workloads directed to a minimal number of targeted abilities. Unlike the traditional model, in which the simultaneous development of many athletic abilities predominates, block-periodized training presupposes the consecutive development of reasonably selected target abilities. The content of block-periodized training is set down in its general principles, taxonomy of mesocycle blocks, and guidelines for compiling an annual plan.

**Seasonal variations in physiological variables of hockey players**

Physiological assessment of athletes is an important process for the characterization of the athlete, monitoring progress and the trained state or ‘level of preparedness’ of an athlete, as well as aiding the process of training program design. Interestingly, the majority of physiological assessments
performed on athletes can also be performed on children with disease, and therefore clinicians can learn a great deal about physiology and assessment of patient populations through the examination of the physiological responses of elite athletes. Wells and Norris (2009) described typical physiological responses of elite athletes to tests of aerobic and anaerobic metabolism and provided a specific focus upon respiratory limitations to exercise performance. Typical responses of elite athletes are described to provide the scientist and clinician with a perspective of the upper range of physiological capacities of elite athletes.

Jeong, et al., (2011) quantified the physiological loads of programmed "pre-season" and "in-season" training in professional soccer players. Data for players during each period were included for analysis (pre-season, n = 12; in-season, n = 10). They monitored physiological loading of training by measuring heart rate and rating of perceived exertion (RPE). Training loads were calculated by multiplying RPE score by the duration of training sessions. Each session was sub-categorized as physical, technical/tactical, physical and technical/tactical training. Average physiological loads in pre-season (heart rate 124 ± 7 beats/min; training load 4343 ± 329 Borg scale/min) were higher compared with in-season (heart rate 112 ± 7 beats/min; training load 1703 ± 173 Borg scale/min) (P < 0.05) and there was a greater proportion of time spent in 80-100% maximum heart rate zones (18 ± 2 vs. 5 ± 2%; P < 0.05). Such differences appear attributable to the higher intensities in technical/tactical sessions during pre-season (pre-season: heart
rate 137 ± 8 beats/min; training load 321 ± 23 Borg scale · min; in-season: heart rate 114 ± 9 beats/min; training load 174 ± 27 Borg scale/min; P < 0.05). Their findings demonstrated that pre-season training is more intense than in-season training. Such data indicated that these adjustments in load are a direct attempt to deliver training to promote specific training adaptations.

Hoff and Helgerud, (2004) stated that top soccer players do not necessarily have an extraordinary capacity in any of the areas of physical performance. Soccer training is largely based on the game itself, and a common recruitment pattern from player to coach and manager reinforces this tradition. New developments in understanding adaptive processes to the circulatory system and endurance performance as well as nerve and muscle adaptations to training and performance have given rise to more effective training interventions. Endurance interval training using an intensity at 90-95% of maximal heart rate in 3- to 8-minute bouts have proved to be effective in the development of endurance, and for performance improvements in soccer play. Strength training using high loads, few repetitions and maximal mobilisation of force in the concentric mode have proved to be effective in the development of strength and related parameters. The new developments in physical training have important implications for the success of soccer players. The challenge both for coaches and players is to act upon the new developments and change existing training practice.

Alberquerque, et al., (2005) studied the 23 components of the Zamora Football Club team, from the second division B of the Spanish football
league, along one season. Seventeen anthropometric variables were studied, together with the percentage of fat according to the Carter formula and body composition (tetra compartmental model). Analysis of variance (ANOVA) was employed for comparisons among groups (p<0.05). In general, the team was found to show a suitable anthropometric development along the season. Both weight and the Body Mass Index decreased along the period studied. With the exception of the suprailiac fold, fat folds decreased as from the first measurement. Fat weight declined, as did its percentage, significant differences being observed between the measurements made at the end of the season and the previous measurements taken. A discrete increase in bone and muscle weight was observed.

Sadhan, Koley and Sandhu (2007) analysed the relationship between cardiorespiratory fitness, body composition and blood pressure in Punjabi collegiate population (n = 148) aged 19 – 26 years. Height and weight were determined by kinanthropometric methods, blood pressure was measured with subjects lying supine after at least 5 min. rest, VO\textsubscript{2} max was measured by Queen’s College Step test. Their results indicated that there was a close association with VO\textsubscript{2} max and percent body fat, and systolic blood pressure in boys, but in girls, correlation was found only between VO\textsubscript{2} max and systolic blood pressure.

Bonaduce, *et al.*, (1998) evaluated the effect of intensive training on cardiac autonomic control in athletes using 24-h heart rate variability analysis. Time and frequency domain measures of heart rate variability were calculated
from 24-h Holter monitoring in 15 high level bicyclists (mean age 21 +/- 4 yr) after 1 month of detraining and after 5 months of vigorous training. At the same times echocardiographic left ventricular mass and dimensions and maximal oxygen consumption (VO$_{2\text{max}}$) were assessed. In detrained athletes, VO$_{2\text{max}}$ values, left ventricular mass and dimensions, and time and frequency domain measures of vagal modulation of heart rate were higher than in a group of untrained subjects of similar age while heart rate and the low-to-high frequency ratio were lower, indicating an enhanced vagal modulation of heart rate in athletes as compared with that in control subjects. After 5 months of vigorous training, left ventricular mass and dimensions and VO$_{2\text{max}}$ increased in athletes, while heart rate decreased further. In contrast, no changes were detectable in time and frequency domain measures of heart rate variability over the entire 24-h and in both waking and sleeping hours.

Nottin, et al., (2002) demonstrated that an increased cardiac vagal control is detectable in detrained athletes; however, after intensive training, despite a significant decrease in heart rate, time and frequency domain measures of heart rate variability reflecting cardiac vagal control remain unchanged. Thus, other mechanisms than changes in cardiac autonomic control could be involved in determining the profound bradycardia of athletes. Stroke volume (SV) response to exercise depends on changes in cardiac filling, intrinsic myocardial contractility and left ventricular afterload. The aim of the present study was to identify whether these variables are influenced by endurance training in pre-pubertal children during a maximal cycle test.
SV, cardiac output (*Doppler echocardiography*), left ventricular dimensions (*time-movement echocardiography*) as well as arterial pressure and systemic vascular resistances were assessed in 10 child cyclists (VO$_2$ max: 58.5 +/- 4.4 mL min$^{-1}$ kg$^{-1}$) and 13 untrained children (UTC) (VO$_2$ max: 45.9 +/- 6.7 mL min$^{-1}$ kg$^{-1}$). All variables were measured at the end of the resting period, during the final minute of each workload and during the last minute of the progressive maximal aerobic test. At rest and during exercise, stroke index was significantly higher in the child cyclists than in UTC. However, the SV patterns were strictly similar for both groups. Moreover, the patterns of diastolic and systolic left ventricular dimensions, and the pattern of systemic vascular resistance of the child cyclists mimicked those of the UTC. SV patterns, as well as their underlying mechanisms, were not altered by endurance training in children. Their result implied that the higher maximal SV obtained in child cyclists depended on factors influencing resting SV, such as cardiac hypertrophy, augmented myocardium relaxation properties or expanded blood volume.

Coutts and Grant (2005) suggested that increasing aerobic capacity will improve performance in team players and officials by allowing them to cover greater distance during a game at higher intensity. Furthermore, they will also increase the number of sprints completed throughout a game, decrease fatigue levels at the end of a game and increase their involvement with ‘the play’. As a coach, player’s aerobic capacity can be improved through well-planned high-intensity training using either interval training or
modified games. By implementing these sessions carefully into the training program will increase the athletes on field performance.

Mahler, et al., (1991) studied the locomotor-respiratory coupling (LRC), or entrainment of breathing, develops in the sport of rowing as a result of training. They prospectively evaluated exercise responses over an 8 month training session (October to May) in 12 female subjects who were members of the Dartmouth College novice rowing team. Progressive, incremental exercise testing was performed on the variable-resistance rowing ergometer (Concept II, Morrisville, VT). To relate the pattern of breathing to the mechanics of rowing, the catch and finish of each rowing stroke during the last 30 s of each minute of exercise were marked on the strip chart paper that recorded inspiratory flow measured by using a heated pneumotachograph. Age was 18 +/- 1 yr (mean +/- SE); weight was 67.5 +/- 2.1 kg. Peak oxygen consumption (VO₂) increased by 10% from October (40.8 +/- 0.6 ml.kg.min⁻¹) to May (P less than 0.001). Chi-square goodness-of-fit analysis was used to assess whether the proportion of inspirations occurring in each of four quadrants of circle plots representing repetitive rowing strokes exercise intensities of 100 watts (W) and peak VO₂ were random or corresponded to a regular pattern of breathing. Although 5 of 12 subjects demonstrated LRC at exercise of 100 W in October, there was no significant change at this submaximal intensity over the training season. Only 2 of 12 subjects showed LRC at peak exercise in October, but there was a significant increase (P = 0.003) in the number of subjects who entrained breathing in Jan (10/12) and May (8/12).
Mahler, Parker and Andresen (1985) evaluated the physiologic changes in rowing performance during the training season, selected cardiorespiratory variables were measured three times at 3-month intervals in seven collegiate women rowers during incremental exercise on the rowing ergometer. Values for maximal oxygen consumption (VO$_2$ max) and peak power production increased by 14% and 18%, respectively, over the 6-month period. Maximal heart rate was unchanged with training. Oxygen-pulse increased significantly (+ 14%) during the training season, while the ventilatory equivalent for oxygen did not change. Oxygen consumption as a percent of VO$_2$ max and heart rate at the anaerobic threshold (AT) decreased during the first 3 months of predominantly aerobic training, but increased significantly in the last 3 months with greater anaerobic conditioning. The changes demonstrated by physiologic testing corresponded to the particular type of training emphasized during the 6-month period. Serial measurements of VO$_2$ max and AT can be used to assess the benefits of specific training. Based on their results, individual guidelines for aerobic and anaerobic conditioning can be developed using the heart rate response at the AT.

Koutedakis, et al., (1992) studied whether seasonal deterioration in physiological variables could be observed in skiers. Eighteen international male British downhill, free-style, and speed skiers were subjected to a maximal treadmill running test, a 30-s Wingate test, and isokinetic dynamometry at the beginning, middle, and end of the 1989-90 competition seasons. Maximal oxygen intake (VO$_2$max) and respiratory anaerobic
threshold (T vent) were among the parameters measured on the treadmill test, while peak and mean power outputs were measured during the Wingate test. During dynamometry, knee flexors and extensors were bilaterally assessed at 1.04 and 3.14 rad.s\(^{-1}\). Mean VO\(_2\)max \((p < 0.01)\) and mean T vent \((p < 0.05)\) were lower at the end compared to the beginning, but not compared to the middle of the competition season. The isokinetic test demonstrated lower mean peak torques at 1.04 rad.s\(^{-1}\), for the knee extensors measured at the end of the season, compared with both the start \((p < 0.01)\) and the middle \((p < 0.05)\). Also at 1.04 rad.s\(^{-1}\), knee flexors produced lower torques at the end than the start of the season \((p < 0.05)\). No further statistical differences were found. They concluded that seasonal deterioration in key physiological variables such as aerobic endurance and muscle strength can be observed in elite alpine skiers, and that in-season fitness training programmes should take account of this.

In a study Koutedakis, et al., (1993) carried out the anthropometric measurements on seven British international male épée fencers, using a maximal treadmill running test, a 20-s Wingate-type test, and isokinetic dynamometry. Testing was conducted on two occasions, 5 to 6 months apart, during mid-off-season \(\text{(preparation)}\) and mid-in-season \(\text{(competition)}\) periods. Maximal oxygen intake \(\text{(VO}_2\text{max)}\) and maximal respiratory exchange ratio \(\text{(Rmax)}\) were among the parameters obtained from the treadmill test, while peak and mean anaerobic power outputs were measured during a 20-s
maximal effort. Knee extensor and flexor muscle forces from both dominant (leading) and non-dominant (trailing) legs were assessed at 1.04, 3.14 and 4.19 rad sec\(^{-1}\). Statistical analyses revealed lower mean VO\(_2\)max \((p < 0.05)\) and mean Rmax values \((p < 0.02)\) at the in-season assessments compared with off-season. In-season testing also demonstrated significantly lower peak torques for both dominant and non-dominant knee extensors compared with off-season assessments at all velocities \((p < 0.05 \text{ to } p < 0.004)\). Furthermore, in-season peak torque for the non-dominant leg flexors was lower \((p < 0.03)\) at 4.19 rad sec\(^{-1}\) than off-season. They concluded that current training practices may account for the observed seasonal variations in performance related physiological parameters in fencers.

Posch, Haglund and Eriksson (1989) selected twenty-three male ice hockey players in a third division amateur ice hockey team were prospectively studied during the 1987-1988 season. O\(_2\) uptake, muscle flexibility, and isokinetic concentric and eccentric leg muscle strength were measured before and after the season. All injuries were recorded by one and the same physician attending all the games: 68 injuries occurred altogether but only six of these led to absence from training or matches. O\(_2\) uptake and muscle flexibility were unchanged during the season, but a significant drop of both concentric and eccentric quadriceps and hamstring torques occurred in spite of the fact that the team played two games and trained twice per week during the entire season. No correlation between the fall in muscle strength
and the injury rate was found. Although many injuries occur in ice hockey, the majority are minor ones that do not lead to absence from playing.

Hakkinen (1993) selected nine members of a female volleyball team served as experimental subjects in order to examine changes in a physical fitness profile during the competitive season consisting of a first season (I) for 10 weeks followed by season II for 11 weeks. The entire season was characterized by 4-5 weekly sessions for playing drills and competitive games and by 2-3 weekly sessions for physical conditioning mostly for strength and explosive strength training. The control group consisted of eight other female volleyball players who trained for physical conditioning during the competitive season 1-2 times per week. Their findings showed that the entire competitive season in experimental subjects led to no changes (from 47.3 +/- 1.7 to 48.1 +/- 3.4 ml/kg/min) in VO$_2$max but a significant ($p < 0.05$) decrease took place in average power in a 30 s anaerobic jumping test. Significant increases took place in the maximal vertical jumping heights in the squat (from 30.3 +/- 1.7 to 31.6 +/- 1.3 cm) ($p < 0.05$) and in the counter movement jump (from 32.8 +/- 1.6 to 34.3 +/- 1.3 cm) ($p < 0.05$) as well as in the spike and block jumps ($p < 0.05$) during competitive season I.

Hakkinen and Sinnemaki, (1991) selected nine bandy players from an elite team they were used as subjects in order to examine effects of the competitive season on a physical fitness profile. The findings demonstrated that the competitive season led to a minor change in maximum oxygen uptake
(from 63.2 +/- 6.0 to 60.8 +/- 3.7 ml x kg\(^{-1}\) x min\(^{-1}\)) but a significant (p less than 0.05) decrease occurred in oxygen uptake at the anaerobic threshold from 48.6 +/- 6.8 to 43.4 +/- 2.3 ml x kg\(^{-1}\) x min\(^{-1}\). Average anaerobic power output during a 60 s maximal work period remained statistically unaltered during the season. A statistically non significant change (from 3233 +/- 493 to 3185 +/- 543 N) took place in maximal strength of the leg extensor muscles. A considerable change occurred during the competitive season in the shape of the isometric force-time curve so that the times of force production lengthened significantly (p less than 0.05) at all positions of the curve. The individual changes during the season in each of the characteristics of the physical fitness profile correlated (p less than 0.05-0.01) with the initial level recorded before the season. They suggested that a competitive season in elite bandy players may lead to considerable decreases in selected characteristics of the physical fitness profile. Their findings suggested that the magnitude and/or the frequency of physical training stimuli might be given more attention also during the competitive season and the individual needs of the players should be taken properly into consideration in the full training program.

Van Ingen Schenau, et al., (1992) selected seven female and eight male elite junior skaters who performed cycle ergometer tests at four different times during the 1987/1988 season. The tests consisted of a Wingate-type 30-s sprint test and a 2.5-min supramaximal test. The subjects were tested in
February, May and September 1987 and in January 1988. Maximal oxygen consumption was measured during the 2.5-min test. With the exception of the maximal oxygen consumption of the women in May which was about 6% lower than in the other three tests, no seasonal changes in the test results could be observed—this, in spite of a distinct increase in training volume (from 10 to more than 20 h.week⁻¹) and training intensity in the course of the season. When the test data were compared to those of elite senior skaters, it appeared that the junior skaters showed the same values for mean power output during the sprint test [14.2 (SD 0.4) W.kg⁻¹ for the men and 12.6 (SD 0.5) W.kg⁻¹ for the women] and maximal oxygen consumption [63.1 (SD 2.8) ml/kg/min for the men and 55.3 (SD 3.5) ml/kg/min for the women, respectively] as found for senior skaters. They found that the effects of training in the skaters had already levelled off in the period before the skaters participated in the investigation.

Svedenhag and Sjodin (1985) studied the seasonal variation in physiological characteristics of elite male runners. Five middle distance (mean age 21 yrs) and 5 long distance runners (23 yrs), all members of the Swedish national track and field team, participated in treadmill tests on 4 occasions over a period of one year: in January, in May, during the highly competitive summer period and the following January. The maximal oxygen uptake (VO₂ max, ml/kg/min) increased successively during the season and was significantly (p less than 0.01) higher during the summer than in the
winter (74.2 to 77.4 ml/kg/min). From the competitive summer period to the second winter the VO$_2$ max (ml/kg/min) showed a significant decrease. The absolute value of VO$_2$ max (1/min) was not significantly changed during this one-year period, however. Running economy was evaluated from oxygen uptake determinations at 15 km/h (VO$_2$ -15) and 20 km/h (VO$_2$ -20). Slightly lower values of VO$_2$ - 15 and VO$_2$ - 20 were noted during the season, and after one year VO$_2$ - 20 was significantly decreased. Such an improvement in running economy with time was also found in a larger group of elite runners (n = 16) when determined from an average of 7 treadmill tests. The running velocity corresponding to a blood lactate concentration of 4 mmol/l increased from January to the summer season. The blood lactate concentration after exhaustion (VO$_2$ max test) increased significantly from January to May.

Hagerman and Staron, (1983) selected nine members of the U.S. Men's Olympic Rowing Team during the in-season (IS) and off-season (OS). Maximum power, VE, VO$_2$, and heart rate were measured during a 6-min rowing ergometer exercise during IS and OS. Per cent body fat and isokinetic quadriceps strength were also determined. Biopsies were removed from the vastus lateralis and analyzed histochemically and morphometrically during OS only. No changes were noted for body composition between IS and OS. VEmax and VO$_2$max increased significantly from OS to IS; absolute VO$_2$max increased from 5.09 to 6.01 l/min and relative values increased from 56.5 to 69.1 ml/kg/min. Power increased 14% from OS to IS while heart rate showed no difference. Leg strength increased significantly at 6 different angular
velocities from IS to OS especially at the lower speeds. Biopsy data revealed an average ratio of 75% slow twitch Type I fibers and 25% fast twitch Type II fibers. Larger fiber diameters were noted for Type II fibers but this difference was not significant. Although seasonal effects were expected, the unusually large differences in metabolic and strength capacities between IS and OS reflect a high degree of training specificity.

White, et al., (1982) selected British Olympic road squad cyclists were monitored during the 1980 racing season to evaluate training for the Moscow Games. Riders demonstrated reductions in body fat index, % body fat and endomorphy (p greater than .05). Graded exercise, using a "Racermate" wind load simulator/racing cycle ergometer system, showed reduced cardiovascular demands to warm-up exercise, and increased cardiovascular index, VO₂ maximum, aerobic/anaerobic threshold shifts during maximal exercise (NS), with no changes in gearing, equivalent road speed, absolute/relative power output and leg power. Compared with "non-select" riders demonstrated lower body fat index, % body fat and endomorphy (p greater than .05), higher Hb and PCV % (p greater than .05) and elevated neuroticism and extraversion (p greater than .05). Furthermore, "select" riders demonstrated lower HR and CV index during warm-up exercise (p greater than .05), and elevated CV index, VO₂ maximum, aerobic/anerobic thresholds during maximal exercise (p greater than .05), resulting from higher gearing, equivalent road speed and absolute/relative power output (p greater than .05).
Yen-Ting and Chen-Kang (2009) studied the performance of elite athletes depending on their technical, physiological and psychological abilities. Different sports require various levels of aerobic, anaerobic, speed, power, agility, and strength capacities. Elite athletes and athletes who aim to become elite usually train year-round with carefully designed training programs. The close monitoring of physical capacities during the entire training period is essential for elite athletes to investigate the effect of the training program and determine if the recovery is sufficient. Their study summarized the changes in aerobic and anaerobic capacity in different training periods in athletes of various sports. In addition to fitness tests, testosterone-to-cortisol ratio may be a useful indicator for the balance between anabolic and catabolic states. Testosterone-to-cortisol ratio may be measured in different training periods to estimate the degree of recovery.

Sjøgaard (1984) studied muscle adaptation to high endurance performance. Muscle biopsies were taken from the m. vastus lateralis of 23 road cyclists, and their VO\textsubscript{2} max was measured repeatedly during the season. At the beginning of their training season, VO\textsubscript{2} max was 56 (37-66) ml/kg/min in competitive amateurs and 71 (64-76) ml/kg/min in elite professionals. Muscle capillary density determined at the same time was correspondingly roughly 30% higher in elite than in competitive cyclists while muscle enzyme activities (CS, HAD, and HK) were 30%-60% higher and LDH 50% lower in elite compared to competitive cyclists. Some elite cyclists were retested 5 months later when each of them had completed more than 15,000 km of
bicycling during training and competition. During this period VO2 max remained unchanged, and the same was true for capillary density, while muscle enzyme activity (CS, HAD, and HK) increased 40%-70%, and LDH slightly decreased. The results suggested that there may not be a close coupling between whole body VO2 max and the oxidative capacity of a local muscle group. Rather, the changes in muscle enzyme activities may be of importance for the regulation of muscle metabolism enhancing the endurance capacity. They suggested that capillary density of the working muscles is of significance for VO2 max.

Powers and Williams (1987) showed that the pulmonary system has not been considered the limiting factor in determining maximal oxygen uptake (VO2 max) in healthy individuals since arterial oxygen-haemoglobin saturation is thought to remain high during intense exercise. However, there appears to be a major exception to this rule. Recent evidence suggests that arterial hypoxaemia results during heavy exercise in well trained individuals with a high VO2 max. Further, the degree of arterial desaturation is inversely related to VO2 max. This exercise-induced hypoxaemia does not appear to be due to hypoventilation although athletes who have limited hyperventilation seem to exhibit the lowest arterial oxygen-haemoglobin saturation. A significant venoarterial shunt has been ruled out as a primary cause of the hypoxaemia based on both experimental and theoretical considerations. Therefore, it appears that the exercise-induced hypoxaemia seen in highly trained athletes during heavy exercise is primarily due to diffusion limitations.
and ventilation-perfusion inequality. It is postulated that incomplete diffusion in the healthy lung may be due to a rapid red blood cell transit time through the pulmonary capillary. Though, literatures suggested that the limits of the human pulmonary system may be reached or even exceeded during intense exercise in some individuals. In light of their findings the role of the pulmonary system as a limiting factor during maximal exercise in the highly trained endurance athlete warrants further investigation.

Williams, Powers and Stuart (1986) examined the relationship between maximal oxygen consumption (VO₂ max) and arterial oxygen-hemoglobin saturation (%SaO₂) during short-term heavy exercise in trained athletes and untrained individuals. Ten trained distance runners and 7 untrained males exercised at 95% of VO₂ max for 3 min. Minute-by-minute measurement of %SaO₂ was obtained via ear oximetry. The correlation coefficients between %SaO₂ and VO₂ max, during exercise were r = -0.68, r = -0.74, and r = -0.72 (P < 0.05) for minutes 1 through 3, respectively. In general those individuals with the highest VO₂ max showed the greatest decrease in %SaO₂. By comparison there was no difference (P > 0.05) in resting %SaO₂ between the trained (96.3 +/- 0.2% [SE]) and the untrained (96.3 +/- 0.4%) subjects. However, at minute 3 of exercise, %SaO₂ was significantly lower (P < 0.05) in the trained subjects (87.0 +/- 0.7%) than in the untrained subjects (92.6 +/- 0.7%). Their data demonstrated that arterial desaturation occurs in healthy,
highly trained endurance athletes during heavy exercise and that the level of the arterial desaturation is inversely related to VO$_2$max.

Clark, *et al.*, (2008) examined season-to-season variations in physiological fitness parameters among a 1st team squad of professional adult male soccer players for the confirmatory purposes of identifying normative responses (*immediately prior to pre-season training (PPS), mid-season (MID), and end-of-season (EOS)*). Test-retest data were collected from a student population on the primary dependent variables of anaerobic threshold (AT) and maximal aerobic power (VO$_2$ max) to define meaningful measurement change in excess of test retest technical error between test-to-test performances. Participants from a pool of 42 professional soccer players were tested over a set sequence of tests during the 3-year period: 1) basic anthropometry, 2) countermovement jump (CMJ) tests 3) a combined AT and VO$_2$ max test. Over the 3-year period there were no test-to-test changes in mean VO$_2$ max performance exceeding pre-defined limits of test agreement (mean of eight measures: 61.6 ± 0.6 ml·kg$^{-1}$·min$^{-1}$). In contrast, VO$_2$ at AT was significantly higher at the MID test occasion in seasons 2 (+4.8%; $p = 0.04$, $p < 0.05$) and 3 (+6.8%; $p = 0.03$, $p < 0.05$). The CMJ tests showed a test-to-test improvement of 6.3% (best of 3 jumps) ($p = 0.03$, $p < 0.05$) and 10.3% (20-s sustained jumping test) ($p = 0.007$, $p < 0.01$) between PPS2 and MID2 and thereafter remained stable. Anthropometrics were unaffected. In summary, despite some personnel changes in the elite cohort between test-to-test occasions, VO$_2$ max values did not vary significantly over the study
which supports previous short-term observations suggesting a general ‘elite’ threshold of 60 ml·kg-1·min. Interestingly, AT significantly varied where VO₂ max was stable and these variations also coincided with on- and off seasons suggesting that AT is a better indication of acute training state than VO₂ max.

Majumdar and Srividhya (2010) initiated to monitor the training load with the magnitude of impact on the hormone concentrations such as testosterone, cortisol and T/C (Testosterone/Cortisol) ratio during the three phases of training (*i.e. preparatory, precompetitive, and competitive phases*) in Indian male swimmers preparing for the 2010 Commonwealth Games. Blood samples were collected at the end of each training phase and hormone concentration was determined by ELISA. Their results revealed that testosterone concentration and the T/C ratio significantly decreased and the cortisol concentration increased in the subsequent periodized cycle. Change in hormone concentration was associated with the intensity and duration of individual exercise sessions. The greatest performance enhancement was realized with the lowest plasma cortisol, highest testosterone, and a high T/C ratio. Monitoring of these hormones also have implications for identifying and preventing overreaching in swimmers.

Podgórski, *et al.*, (2011) determined the influence of maximal physical effort on the acid-base balance in female field hockey players in a yearly training cycle. Twelve members of the National Polish Field Hockey Team were tested once in the preparatory and twice in the competitive period of one
training macrocycle. Using a portable ergospirometry system, the athletes were examined on a motorized treadmill to determine their maximal oxygen uptake ($\text{VO}_2\max$) and ventilatory threshold (VT). Lactate (LA) concentration in capillary blood was assessed to calculate the intensity of physical effort and metabolic response. The biochemical parameters of acid-base balance were determined using a blood gas analyzer. Mean $\text{VO}_2\max$ VT values indicated a medium level of the tested competitors' aerobic fitness. The highest $\text{VO}_2\max$ and VT values were observed at the beginning of the competitive period. After each test, the lactate concentration was elevated, while pH, concentration of bicarbonate ions, and base excess rapidly decreased. All calculated differences in biochemical parameters measured at rest and post-exercise were highly significant. The lowest differences in pH and lactate concentration were observed in the mid-competitive period. Those biochemical changes showed that metabolic acidosis was present in all three examinations. The lowest acid-base balance disturbances were observed in the mid-competitive period.

Manna, Khanna and Dhara (2010) investigated the effect of training on selected anthropometric, physiological and biochemical variables of elite field hockey players. A total of 30 Indian male field hockey players (age: 23.00-30.00 yrs) volunteered for this study. The training sessions were divided into 2 phases (a) Preparatory Phase (PP, 8 weeks) and (b) Competitive Phase (CP, 4 weeks). The training programme consist of aerobic, anaerobic and skill
development, and were completed 4 hrs/day; 5 days/week. Selected variables were measured at zero level (baseline data, BD) and at the end of PP and CP. A significant increase (P<0.05) in LBM, back and hand grip strength, serum level of urea, uric acid and HDLC; and a significant decrease (P<0.05) in body fat, sub-maximal exercise heart rate and recovery heart rate, hemoglobin, total cholesterol, triglyceride and LDLC were noted in PP and CP of training when compare to BD. No significant change was noted in stature, body mass, HRmax, resting heart rate, VO\(_2\)\(_{\text{max}}\) and anaerobic power of the players after the training. Since the data on field hockey players are limited in India, the present study may provide useful information to the coaches to develop their training programme.

Almansba, et al., (2010) assessed the maximal oxygen uptake (VO\(_2\)\(_{\text{max}}\)) of judoists in consecutive training periods: a) GPP, b) SPP, c) CP. They selected fifteen male judoists aged of 22 ± 7 years participated in this study. Their sport levels varied from departmental (group D, \(n = 7\)) to inter-regional (group IR, \(n = 8\)) experience. The standing height was measured with a wall-mounted wooden stadiometer. An electronic weighing scale was used to assess the body mass (W) in each period of preparation. The VO\(_2\)\(_{\text{max}}\) was assessed using the multistage 20-meters shuttle run test. Their result showed that the sport level had a statistically significant bearing (p<0.001) of judo competitors weight, but not with the time factor. The pattern of changes in weight in both groups IR and D was different during the training period. They also noticed that the weight of group D members decreased in SP period and
increased in CP. We didn’t observed a significant difference of O2max between group D and IR (95% Tukey HSD intervals are overlapping). The competition level affects significantly the HRmax (p<0.001). Group D presented higher HRmax values in three testing periods (GPP, SP and CP) than IR group. The time factor was close to reach significance level. They concluded that VO2max of judoists changes in consecutive training periods. The HRmax is linked to the sport level but it less sensitive at workload variations than the HRmax. A moderate aerobic state doesn’t imply a low judo performance. Tests more specifically related to judo could be projected to provide more information about this aspect.

Magal, et al., (2009) examined the changes in various aerobic and anaerobic physical performance measures in male National Collegiate Athletic Association (NCAA) Division III soccer players during the competitive soccer season. Twelve starters of the men's soccer team (mean +/- SD; age = 20.0 +/- 0.9 years, height = 175.7 +/- 8.1 cm, body mass = 73.9 +/- 11.00 kg, body mass index [BMI] 24.0 +/- 3.0 kg.m2, and percent body fat = 10.6 +/- 5.4%) were tested at the beginning (PRS) and the end (POS) of the collegiate soccer season. Each experimental trial included a maximal aerobic capacity test (VO2max); 10-, 30-, and 40-m sprints; pro-agility test; and the Wingate anaerobic power test (WAnT). From PRS to POS, VO2max significantly increased (51.05 +/- 5.97 vs. 54.64 +/- 4.90 ml.kg-1.min-1), and the 10- and 30-m sprint were significantly lower (2.03 +/- 0.15 vs. 1.96 +/- 0.11 seconds and 4.72 +/- 0.26 vs. 4.51 +/- 0.24 seconds, respectively).
Anthropometric measures, 40-m sprint, pro-agility test, and WAnT were not significantly different between PRS and POS. Their results of the study indicated that NCAA Division III male soccer players appear to improve aerobic and anaerobic performance measures during the competitive soccer season.

Gross, et al., (2009) compared exhaustive ramp cycling and squat (SJ) and countermovement jumping (CMJ) performance in elite males before and after their competitive season. In postseason compared with preseason: 1) maximal oxygen uptake (VO$_2$ max) normalized to bodyweight was higher (55.2 +/- 5.2 vs 52.7 +/- 3.6 ml/kg/min, P < 0.01), but corresponding work rate (W) was unchanged; 2) at ventilatory thresholds (VT), absolute and relative work rates were similar but heart rates were lower; 3) VO$_2$/W slope was greater (9.59 +/- 0.6 vs 9.19 +/- 0.4 mL O$_2$/min/w, P = 0.02), with similar flattening (P < 0.01) above VT1 at both time points; and 4) jump height was greater in SJ (47.4 +/- 4.4 vs 44.7 +/- 4.3 cm, P < 0.01) and CMJ (52.7 +/- 4.6 vs 50.4 +/- 5.0 cm, P < 0.01). It is believed that aerobic capacity and leg power were constrained in preseason and that improvements primarily reflected an in-season recovery from a fatigued state, which was caused by incongruous preseason training. Residual adaptations to high-altitude exposure in preseason could have also affected the results. Nonetheless, modern alpine skiing seemingly provides an ample cardiovascular training stimulus for skiers to maintain their aerobic capacities during the racing season. They concluded that that aerobic fitness and leg explosiveness can be
maintained in-season but may be compromised by heavy or excessive preseason training. In addition, ramp test VO$_2$/W slope analysis could be useful for monitoring both positive and negative responses to training.

Durocher, Leetun and Carter (2008) examined the lactate threshold (LT) and maximal aerobic capacity with a sport-specific skating protocol throughout a competitive season in collegiate hockey players. They hypothesized that maximal aerobic capacity and skating velocity at LT would increase as the season progressed. They selected sixteen Division I college hockey players performed a graded exercise skating protocol to fatigue at 3 different times (pre, mid, and postseason). Subjects skated for 80 s during each stage, followed by 40 s of rest to allow for blood lactate sampling. Velocity at LT was similar during preseason (4.44 +/- 0.08 m.s$^{-1}$) and postseason (4.52 +/- 0.05 m.s$^{-1}$) testing, but was significantly elevated at midseason (4.70 +/- 0.08 m.s$^{-1}$; $p < 0.01$), compared with preseason. In contrast, LT as a percentage of maximal heart rate (HRmax) was unchanged throughout the season. HRmax remained constant throughout the season, at approximately 190 beats.min$^{-1}$. Preseason maximal aerobic capacity (48.7 +/- 0.8 mL.kg$^{-1}$.min$^{-1}$) was significantly higher than that at postseason (45.0 +/- 1.1 mL.kg$^{-1}$.min$^{-1}$; $p < 0.01$). They concluded that skating velocity at LT improved from pre- to midseason, but this adaptation was not maintained at postseason. Additionally, maximal aerobic capacity was reduced from pre- to postseason. Their findings suggest a need for aerobic training throughout the college hockey season.
Miller, et al., (2007) measured aerobic capacity and body composition at 3 time points over a 1-year period in 26 Division 1A women soccer players from Texas A&M University, in order to determine whether there were seasonal changes in these parameters. Subjects were tested in December, immediately following a 4-month competitive season; in April, following 15 weeks of strength and conditioning; and immediately prior to the start of the regular season in August, following a 12-week summer strength and conditioning program. A periodized strength and conditioning program design was incorporated in order to optimize anaerobic and oxidative capacity immediately prior to the regular competitive season. Significant differences in VO$_2$max were measured between August (49.24 +/- 4.38 ml x kg(-1) x min(-1)) and December (44.87 +/- 4.61 ml x kg(-1) x min(-1)). No significant changes in aerobic capacity were found between April (47.43 +/- 4.01 ml x kg(-1) x min(-1)) and August (49.64 +/- 5.25 ml/kg/min). Significant increases in body fat were measured between August (15.71 +/- 2.92%) and December (18.78 +/- 2.79%), before and after the competitive season, respectively. No significant changes in body fat were found between April (16.24 +/- 2.95%) and August (15.71 +/- 2.92%). The results of their study suggested that decreases in muscle mass over the course of a regular competitive season contribute to decreases in aerobic capacity in collegiate women soccer players. Although it was unknown whether those decrease in muscle mass is the result of inadequate training or a normal adaptation to the physiological demands imposed by soccer, they suggested that resistance
training volume should be maintained during the competitive season, in order to maintain preseason levels of muscle mass.

Losnegard, et al., (2012) in their study monitored changes in aerobic and anaerobic capacities and performance in a group of elite cross-country skiers during a full sport season. Thirteen male (age; 23 ± 2 yrs, height; 182 ± 6 cm, body-mass; 76 ± 8 kg, V2 roller ski skating VO₂max; 79.3 ± 4.4 ml/kg/min or 6.0 ± 0.5 L/min) were tested during the early-, middle- and late preparation phase: June (T1) - August (T2) - October (T3), during the competition phase: January/February (T4) and the following early pre-competition phase: June (T5). O₂-cost during submaximal efforts and VO₂peak, accumulated oxygen deficit (ΣO₂-deficit) and performance during a 1000m test were determined in the V2 ski skating technique on a rollerski treadmill. Subjects performed their training on an individual basis and detailed training logs were categorized into different intensity zones and exercise modes. Total training volume was highest during the summer months (early preseason) and decreased towards and through the winter season, while the volume of high intensity training increased (all P < 0.05). There was a significant main effect among testing sessions for 1000 m time, O₂-cost and ΣO₂-deficit (Cohen’s d effect size; ES = 0.63-1.37, moderate - large, all P < 0.05). In general, the changes occurred between T1 and T3 with minor changes in the competitive season (T3-T4). No significant changes were found in VO₂peak across the year (ES = 0.17, trivial). They concluded that
the training performed by elite cross-country skiers induced no significant changes in VO$_2$peak, but improved performance, O2-cost and ΣO2-deficit.

Knoepfli, et al., (2004) compared the changes in circulating energy sources during prolonged exercise in off season (OS) and pre-season (PS) training of triathletes. They selected nine athletes of the Swiss national triathlon team (three female, mean (SD) age 28.7 (4.9) years, height 169.8 (6.0) cm, weight 57.0 (6.2) kg, VO$_2$max 66.5 (5.3) ml/min/kg; six male, mean (SD) age 24.0 (4.1) years, height 181.4 (6.9) cm, weight 73.5 (6.0) kg, VO$_2$max 75.9 (4.9) ml/min/kg) were tested twice (2.5 months apart) during a 25 km aerobic capacity test run at the end of the OS and just before the season. The average training load during the OS was 9.9 h/week, and it was increased to 14.4 h/week in the PS. With heart rates as reference, exercise intensity during the aerobic capacity test was 97.0 (4.9)% of the anaerobic threshold and 91.2 (4.5)% of VO$_2$max. Blood samples were collected before, during, and after the aerobic capacity test. Samples were collected every 5 km during three minute rest intervals. The result of their study showed that triglyceride (TG), free fatty acids, cholesterol, high density lipoprotein cholesterol, glucose, insulin, lactate, and changes in plasma volume. A two factor (season by distance) repeated measures analysis of variance revealed an increase in capacity for prolonged exercise in the PS by a decrease in running intensity during the aerobic capacity test (% of speed at 2.0 mmol/l lactate threshold, p = 0.008), an increase in running speed at the anaerobic threshold (p = 0.003) and at 4.0 and 2.0 mmol/l (p<0.001) of the lactate threshold. A
significant season by distance interaction was found for TG (p<0.001). TG concentrations peaked at 5 km and decreased logarithmically throughout the OS (1.48 (0.34) to 0.86 (0.20) mmol/l) and PS (1.90 (0.31) to 0.73 (0.18) mmol/l) tests. From the OS to the PS, there was an increase in the difference in TG at 5-15 km with a concomitant increase at 2.0 mmol/l of the lactate threshold. The peak TG concentrations at 5 km followed by a logarithmic decrease suggest that TG may also provide circulating energy. A greater logarithmic decrease in TG occurred in the PS than in the OS, indicating a higher rate of use. There was an increase in the difference in TG at 5-15 km similar to the increase in the speed at 2.0 mmol/l of the lactate threshold between the two seasons. Glucose, insulin, lactate, and free fatty acids were similar in the two seasons. They concluded that free fatty acid and TG concentrations were much higher than expected, and the two training seasons showed significantly different patterns of TG concentration during prolonged running. These responses may be related to aerobic capacity of prolonged exercise.

Game and Bell (2006) examined the effect of a competitive season and environmental factors on pulmonary function and aerobic power in varsity hockey players. Fourteen male subjects completed testing before and after a 7-month varsity hockey season within ice arena conditions. All subjects completed an aerobic power (VO₂ max) test on a cycle ergometer. Pulmonary function tests were performed at rest and 1, 10, 15, and 25 min after the (VO₂ max) test. The arena environment was monitored during testing and
throughout the season for temperature, relative humidity, gaseous chemicals, moulds, and fungi. There was no change in (VO$_2$ max) during the season. The percent change in forced expiratory flow in 1 s (FEV1) post-exercise compared to resting FEV1 and forced vital capacity (FVC) after the (VO$_2$ max) test were significantly lower after the season. The arena temperature and relative humidity ranged between 13 and 16 degrees C and between 30% and 45% over the course of the season. Sulfur dioxide (0.7-4.5 ppm) was found in the arena and no airborne moulds unique to the dressing room environment were found to exceed Health Canada's guideline of 50 CFU/m(3) for indoor air quality. They concluded that some hockey players experience limitations to pulmonary function over the course of a competitive season.

Kay and Gill (2004) assessed whether any characteristic patterns of heart rate (HR) responses could be identified in National Rugby League (NRL) referees (n= 6) during matches played in the 2001 season. The data have been plotted and discussed, in order that exercise program planning practitioners may gain improved understandings of the physiological requirements for referees. Some specific training suggestions have also been made. The HR was recorded every five seconds throughout six competition NRL matches; using a heart rate monitor with a built-in memory. The specific magnitudes of referees' HR mean values varied between individuals, possibly due to specific game intensities, referee fitness, and age. All referees however exhibited similar HR response patterns; characterised by frequent (13-20 per match) large transient upward and downward shifts (>20 beats/minute).
Periods of elevated HR extended for between five sec and eight min at a time, and were further characterised as a typical cyclic wave of HR elevation and recovery (ranging from 99.2 +/- 12.4 beats/minute to 176.5 +/- 11.8 beats/minute) [mean +/- 95% CI], with a work to rest ratio of 2:1. Steady state HR was not achieved at any time during any match. They concluded that training and fitness assessment of athletes should reflect their specific demands; some specific recommendations have therefore been provided.

Perini, et al., (2006) evaluated the changes in athletes' physical fitness due to seasonal training are associated with changes in cardiovascular autonomic control, nine swimmers (three males and six females; aged 14-18 years) were evaluated before and after 5 months of training and competitions. Maximal oxygen consumption (VO2max) and ventilatory threshold were determined during a maximal test; heart rate (HR) and blood pressure (BP) variabilities' power spectra were calculated at rest (supine and sitting positions) and in the recovery of two exercises at 25 and 80% pre-training VO2max. At the end of the season: (a) VO2max and ventilatory threshold increased respectively by 12 and 34% (P<0.05); (b) at rest, HR decreased by 9 beats/min in both body positions, whereas BP decreased in supine position only by 17%. No change in low frequency (LF, 0.04-0.15 Hz) and high frequency (HF, 0.15-1.5 Hz) normalized powers and in LF/HF ratio of HR variability and in LF power of systolic BP variability was observed. In contrast, a significant increase in HF alpha-index (about 12 ms mmHg^-1) was found; (c) during recovery no change in any parameter was observed.
Seasonal training improved exercise capacity and decreased resting cardiovascular parameters, but did not modify vagal and sympathetic spectral markers. The increase in alpha-index observed at rest after the season and expression of augmented baroreflex sensibility indicated however that HR vagal control could have been enhanced by seasonal training. Their findings suggested that autonomic system might have played a role in short-term adaptation to training.

**Maturational changes in muscle strength**

Gabbett and Georgieff (2007) investigated the physiological and anthropometric characteristics of junior volleyball players competing at the elite, semi-elite, and novice levels and to establish performance standards for these athletes. One hundred and fifty-three junior national (N = 14 males; N = 20 females), state (N = 16 males; N = 42 females), and novice (N = 27 males; N = 34 females) volleyball players participated in this study. Subjects underwent measurements of standard anthropometry (*body mass, height, standing reach height, and sum of 7 skinfolds*), lower-body muscular power (*vertical jump and spike jump*), upper-body muscular power (*overhead medicine ball throw*), speed (*5-m and 10-m sprint*), agility (*T-test*), and estimated maximal aerobic power (*multistage fitness test*) during the competitive phase of the season, after obtaining a degree of match fitness. Significant differences (*p < 0.05*) were detected among junior national, state, and novice volleyball players for height, standing reach height, skinfold thickness, lower-body muscular power, agility, and estimated maximal
aerobic power, with the physiological and anthropometric characteristics of players typically improving with increases in playing level. Male players were taller, heavier, leaner, and had greater standing reach height, speed, agility, muscular power, and estimated maximal aerobic power than female players. Their findings provided normative data and performance standards for junior volleyball players competing at the elite, semi-elite, and novice levels. Given the improvements in lower-body muscular power, agility, and estimated maximal aerobic power with increased playing level, and given the importance of these qualities to competitive performances, conditioning coaches should train these qualities to improve the playing performances of junior volleyball players.

Gabbett (2005) compared the physiological and anthropometric characteristics of specific playing positions and positional playing groups in junior rugby league players. Two hundred and forty junior rugby league players underwent measurements of standard anthropometry (body mass, height, sum of four skinfolds), muscular power (vertical jump), speed (10, 20, and 40 m sprint), agility (L run), and estimated maximal aerobic power (multi-stage fitness test) during the competitive phase of the season, after players had obtained a degree of match fitness. The result of their study showed that props were significantly (p<0.05) taller, heavier, and had greater skinfold thickness than all other positions. The halfback and centre positions were faster than props over 40 m. Halfbacks had significantly (p<0.05) greater estimated maximal aerobic power than props. When data were
analysed according to positional similarities, it was found that the props positional group had lower 20 and 40 m speed, agility, and estimated maximal aerobic power than the hookers and halves and outside backs positional groups. Differences in the physiological and anthropometric characteristics of other individual playing positions and positional playing groups were uncommon. They concluded that few physiological and anthropometric differences exist among individual playing positions in junior rugby league players, although props are taller, heavier, have greater skinfold thickness, lower 20 and 40 m speed, agility, and estimated maximal aerobic power than other positional playing groups. Their findings provided normative data and realistic performance standards for junior rugby league players competing in specific individual positions and positional playing groups.

**Summary of Literature**

There is only a small amount of published literature on the physical demands of hockey and no literature exists describing both technical and tactical aspects of match performance. The early studies of Ghosh *et al* (1991) and Boyle *et al* (1994) provided some basic information prior to the rule changes and Johnston *et al* (2004) added more recent data to this. The papers have been surpassed by Spencer *et al* (2004).

Hockey is a game of strength, speed, and skill (Keogh *et al*., 2003; Jennings *et al*., 2012). It requires a combination of power, endurance, agility and flexibility to exploit advantage over their opponents on the playfield...
In competitive matches aerobic system place a heavy demand which determine playing ability. Aerobic capacity and heart rate are key performance measures to assess performance (Boyle, et al., 1994; Macleod & Sunderland, 2012).

In most sports training for successful competition has become a year-long challenge. To assist in preparation, an athlete’s year is often periodised or divided into distinct phases where training is reduced or increased according to competition commitments. Measuring physiological parameters throughout a periodized training year and across consecutive year give an assessment of how physical fitness and physiological variables fluctuates across the year. It is important to assess existing training schedules through rigorous sport specific fitness testing of athletes at defined points in the periodized training year. This will evaluate both physical fitness and physiological variables and the existing training strategies.

Hockey demands speed, power, agility, flexibility, strength and core strength. These parameters fluctuate across periodized training year. Earlier, Astorino et al., (2004) evaluated changes in physical fitness parameters during a competitive field hockey season and found that VO2max was maintained across the season while maximal strength declined. Similarly, Mercer et al., (1995) stated that pre-season conditioning did provide sufficient stimulus to improve aerobic capacity but that this inhibited explosive leg strength (vertical jump height). Explosive power and strength determines
speed and agility of hockey players there by which undergo fluctuations as a result of different types of training which enhance fitness parameters. However, Kraemer et al., (1993) demonstrated attenuation in muscle power and strength adaptations after concurrent strength and endurance training compared to a single mode of training.

It has been well-documented that in untrained trained subjects, aerobic training programs with sufficient intensity, duration, and length will increase VO₂max by approximately 10-20% (Mahler, et al., 1991). However, athletes with adequately developed aerobic capacities generally showed no change in VO₂max after training programs or competitive seasons. Research in athletes in ‘technical’ sports in which performance is principally determined by skill, have suggested either reduced or unchanged aerobic fitness following training and competition seasons.

In addition, these athletes in ‘technical’ sports may spend considerable training time and effort on specialized techniques, thus reduce the amount of training on cardiovascular capacity. Therefore, they may maintain rather than change their aerobic fitness over year-round training and competition. An international study from Poland showed that VO₂ max elite hockey players greater during precompetitive season and another study from India by Manna, Khanna and Dhara (2010) in their study showed an increasing trend but not significant change in maximal aerobic capacity (VO₂max) and heart rate in the senior elite field hockey players in preparatory phase and competitive
phase when compared to base line data. This was the unique study undertaken on RDT hockey academy hockey players of two different age groups.

Muscular strength is closely related to muscle size or cross sectional area, with a larger muscle being able to generate more force. There is a natural increase in strength approximately 18 months after an adolescents’ growth spurt (Stratton, 2005). This increase is linked to increasing levels of circulating androgens - particularly testosterone. This may play a significant role in increasing muscular strength in hockey players of RDT academy (Gabbett, 2005). Care must be taken when interpreting effects of training interventions or when evaluating fitness levels throughout the season.

Increasing endurance capacity can lead to several positive effects on field adaptations such as increased distance covered, intensity of play and number of sprints performed. Similarly, increasing parameters of strength and power can influence performance through increasing ability to sprint, jump, strength and agile. These variables should be assessed at different time points across the season to evaluate training, monitor fitness and to provide details of any seasonal variation in fitness. There is an anecdotal perception that fitness peaks in the end of specific preparatory phase, is maintained throughout the competitive phase and declines towards the end of the season. However, this is the first study taken to know the physical fitness and physiological difference between different age groups of RDT hockey academy hockey players during two years of periodized training year. The purpose of this
study is to investigate the changes on selected physical fitness and physiological profile during two years of systematic training program in RDT Hockey Academy Ananthapur.