CHAPTER - 2
REVIEW OF RELATED LITERATURE

A literature review can be defined as the selection of available documents (both published and unpublished) on the topic, which contain information, ideas, data and evidence written from a particular standpoint to fulfill certain aims or express certain views on the nature of the topic and how it is to be investigated, and the effective evaluation of these documents in relation to the research being proposed (Hart, 1998).

According to Bruce (1994) "Typically, the literature review forms an important chapter in the thesis, where its purpose is to provide the background to and justification for the research undertaken.” The purpose of the literature review is to locate the research project, to form its context or background, and to provide insights into previous work (Blaxter et al., 2006).

In this study, the different aspects of the volleyball players such as selected components of physical fitness, anthropometric measurements, body composition, somatotyping and physiological variables has been studied. In order to study these aspects thoroughly the literature has been divided into three parts. In the first part studies related to various games and sports, in second part studies related to volleyball game have been studied and in the third part the studies related to respiratory functions have been covered.

2.1 STUDIES RELATED TO VARIOUS GAMES

Dureha (1984) conducted a study by comparing the selected motor fitness components i.e. agility, speed, explosive strength, endurance along with selected anthropometric variables of offensive and defensive hockey players. Fifty male college students from Gwalior were selected as the subject of the study, it was found that there was no significant difference between offensive and defensive hockey players in selected motor fitness components and selected anthropometric variables.

Sharratt et al. (1986) conducted a study to provide baseline physiological data which have been used in the prescription of individual training programs for freestyle wrestlers. Results showed generally, the Canadian wrestlers have a physiological profile similar to elite wrestlers from other countries. Maximal aerobic power is
comparable to or greater than previously reported values and anaerobic capacity and upper body strength are less than values reported for other elite athletes.

Sidhu et al. (1989) examined the physique of national level police players of hockey, football, basketball and volleyball in 1987 and showed that the volleyball and football players are significantly more endomorphic than the hockey players. Hockey and football players were the least ectomorphic of all the categories.

Fry and Morten (1991) conducted a study to determine the kinanthropometric profile of selected paddlers and the non-selected paddlers. Selected paddlers were significantly taller (standing and sitting height), heavier and had large upper arm and forearm girths than non-selected paddlers. There were no significant differences in chest girth, biacromial breadth and the sum of two skinfolds between the two groups.

Dey et al. (1993) conducted a study to assess the morphological and physiological characteristics of Indian national kabaddi players. 25 national kabaddi players, mean age 27.91 years were selected as subjects. They were investigated for their physical characteristics, body fat, lean body mass and somatotype. The physiological characteristics assessed included back strength, maximum oxygen uptake capacity and anaerobic capacity and related cardiorespiratory parameters, oxygen pulse, breathing equivalent, maximum pulmonary ventilation, maximum heart rate. Results showed that the mean percentage body fat of kabaddi players was found to be higher than normal sedentary people. Their physique was found to be endomorphic mesomorph. Physical characteristics, percentage body fat, somatotype, maximum oxygen uptake capacity and anaerobic capacity and other cardiorespiratory parameters were compared with other national counterparts.

Krawczyk et al. (1997) evaluated somatotypes of 300 athletes representing various sports. 28 volleyballers, 54 rowers, 20 light-weight rowers, 51 Greco-Roman wrestlers, 35 freestyle wrestlers, 66 judokas, 32 boxers, 14 karate fighters (aged 19-32 yr.) were analyzed as subjects over a period of 2 years. As a control group, 198 well physically build students of aged 19-21 years were randomly selected. The values of body build factors were compared within the population studied and obtained results were compared with international participants of Olympic Games or European Championships. Result showed that the particular groups of athletes were highly
differentiated in respect of somatotype, the within-group variability being lower than in the control group. When compared with other groups of world elite athletes, the subjects studied had somewhat lower mesomorphy and higher endo or ectomorphy component.

**Gabbett (2000)** investigated the physiological and anthropometric characteristics of amateur rugby league players. Thirty five amateur rugby league players were measured for height, body mass, percentage body fat, muscular power, speed and maximal aerobic power. The 10 m and 40 m sprint, vertical jump, percentage body fat and multistage fitness test results were 20-42% poorer than previously reported for professional rugby league players. Compared with forwards, backs had significantly lower body mass and significantly greater speed during the 40 m sprint. Values for percentage body fat, vertical jump, 10 m sprint and maximal aerobic power were not significantly different between forwards and backs. When compared with professional rugby league players, the training status of amateur rugby league players was 30-53% lower, with players devoting less than three hours a week to team training sessions and about 30 minutes a week to individual training sessions. The training time devoted to the development of muscular power, speed and aerobic fitness did not differ significantly between forwards and backs.

**Mermier et al. (2000)** identified the physiological and anthropometric determinants of sport climbing performance. Forty four climbers (24 men and 20 women) of various skill level and 10 to 44 years of experience were evaluated. Measured anthropometric variables for each subject were height, weight, leg length, arm span, % body fat and physiological variables were knee and shoulder extension, knee flexion, grip and finger pincer strength, bent arm hang, grip endurance, hip and shoulder flexibility and upper and lower body anaerobic power. Result showed that the principal components analysis procedure extracted three components. These were labeled training, anthropometric and flexibility on the basis of the measured variables that were the most influential in forming each component. The results of the multiple regression procedure indicated that the training component uniquely explained 58.9% of the total variance in climbing performance. The anthropometric and flexibility components explained 0.3% and 1.8% of the total variance in climbing performance respectively. It was concluded that the variance in climbing performance can be
explained by a component consisting of trainable variables. More importantly, the findings do not support the belief that a climber must necessarily possess specific anthropometric characteristics to excel in sport rock climbing.

**Montes et al. (2000)** undertook a study to investigate the eye-hand and eye-foot visual reaction time among young soccer players with non-soccer players. Subjects were 53 young male soccer players and 60 young male non-soccer players selected as a control group. Soccer players and non soccer players were divided in three categories in each group ages of 8 to 9 year, 10 to 11 year, and 12 to 13 year. Variables were eye-hand and eye-foot visual reaction times. Results showed that there was statistically significant difference between eye-hand and eye-foot reaction times between players and non players. There was no correlation between visual reaction times and age. Eye-hand and eye-foot visual reaction times were found to be different between the two groups evaluated. There were also differences between soccer and non-soccer players, with the soccer players demonstrating faster reaction times.

**Ostojic (2000)** conducted a study on 32 players which were selected as subjects and further divided into two group’s squad A of elite players and squad B of non-elite players. The structural and functional characteristics of elite Serbian soccer players compared with non-elite counterparts. Results showed that the subjects from squad A were older and more experienced as compared to squad B. Players from squad B had significantly lower estimated VO$_{2\text{max}}$ values as compared with squad A. The highest heart rate frequencies during the last minute of the 20-m shuttle run test were lower in squad A. Vertical jump height was significantly higher in Squad A and estimated percentages of fast muscle fibers were higher in Squad A as compared to Squad B. The results indicated a strong relationship between aerobic fitness, anaerobic power and performance results in elite soccer.

**Reilly et al. (2000)** investigated the anthropometric and physiological characteristics of soccer players. Various measurements have been used to evaluate specific aspects of the physical performance of both youth and adult soccer players. Midfield players and full-backs have the highest maximal oxygen intakes and perform best in intermittent exercise tests. On the other hand, midfield players tend to have the lowest muscle strength. Although these distinctions were evident in adult and elite youth players, their existence must be interpreted circumspectly in talent identification and
A range of relevant anthropometric and physiological factors can be considered which were subject to strong genetic influences stature and maximal oxygen intake. It was concluded that anthropometric and physiological criteria do have a role as part of a holistic monitoring of talented young players.

**Frenkl et al. (2001)** conducted a study to describe the selected anthropometric and exercise physiological characteristics of Hungarian athletes. The subjects were 25 water polo players, 24 paddlers and 20 modern pentathlonists. Results showed that differences in mean height, body mass and body composition characteristics were significant. The greatest oxygen uptake comparative to body mass was found in the modern pentathlonists and the lowest one in the water polo players.

**Grant et al. (2001)** conducted a study on three groups of females: group 1 comprised 10 elite climbers, group 2 consisted of 10 recreational climbers and group 3 comprised 10 physically active individuals. The tests included finger strength (grip strength, finger strength measured on climbing-specific apparatus), flexibility, bent arm hang and pull-ups. Regression procedures (analysis of covariance) were used to examine the influence of body mass, leg length, height and age. For finger strength, the elite climbers recorded significantly higher values than the recreational climbers and non-climbers. For grip strength of the right hand, the elite climbers recorded significantly higher values than the recreational climbers only. The results suggest that elite climbers have greater finger strength than recreational climbers and non-climbers.

**Melhim (2001)** conducted a study on aerobic and anaerobic power responses to the practice of taekwon-do and their beneficial effects on cardiovascular fitness and general physical ability. Nineteen taekwon-do players with an average age of 13.8 years were assessed as subjects. The subjects were assessed for resting heart rate, aerobic power, anaerobic power and anaerobic capacity. Significant differences were observed in anaerobic power and anaerobic capacity. The absolute anaerobic capacity increased by about 61.5% and that relative to body weight increased by about 62%. The practice of taekwon-do promotes anaerobic power and anaerobic capacity, but not aerobic power, in male adolescents.

**Ibnziaten et al. (2002)** analyzed the body composition of male school children with an age range of 10–14: players from 11 League teams. The sample corresponds to
29.32% of the total population (854). Following variables: eight skinfolds, six lengths, eight heights, thirteen girths or perimeters, and nine diameters were measured. The results showed that these athletes are taller, weigh more and have a larger span than the athletes of other studies. From ages 10 to 14, the percentage of fat mass decreases, and a change in the distribution of subcutaneous fat is observed.

**Singh and Koley (2002)** tested skinfold thickness of seventy one sprinters, sixty five long distance runners, twenty six high hurdlers and twenty four low hurdlers of inter-university, national and international level Indian athletes. The result showed highly significant differences in subscapular skinfold between sprinters and long distance runners and between long distance runners and high hurdlers. There were statistically significant differences in suprailliac skinfold between sprinters and long distance runners. No significant differences were found in between any other groups.

**Strudwick et al. (2002)** carried a study to compare the anthropometric and performance characteristics of elite players in two football codes. Subjects were 19 professional soccer players and 33 inter-county Gaelic football players. Measurements were made on members of a Premier League soccer team throughout their regular season, whilst the Gaelic footballers were members of the Mayo squad preparing for the 1999 All-Ireland championship. The stature was significantly greater in the soccer players compared to the Gaelic footballers. Performances in the 10-m and 30-m sprints and in vertical jump were superior in the soccer group compared to the Gaelic footballers.

**Chan et al. (2003)** conducted a study on 20 Subjects (10 males and 10 females) of local taekwon-do clubs in London, U.K. The height, weight, girths, breadths and skinfold thicknesses at 6 sites were measured. Body composition was expressed in terms of reverse ponderal index, sum of skinfolds as well as proportional weight and proportional sum of skinfolds. T-tests with a Dunn-Sidak-adjusted alpha were applied. Results showed that there were no difference found in somatotype attitudinal distance, the women had a higher endomorphy rating than the men. No differences were found in the meso- and ectomorphy components. The females had a significantly higher absolute sum of six skinfolds than the males.

**Oxizoglou and Hatzimanouil (2004)** conducted a study to measure and to compare the morphological characteristics and motor abilities of strength, speed and agility,
between selected team handball players from Yugoslavia and Greece. Participants were 21 Greek athletes and 20 Yugoslavian athletes. The examinations contained measurements for morphological characteristics and motor abilities of strength, speed and agility in accordance with International measurements and instruments. The results showed that Yugoslavian players had a significant difference than Greek players in all morphological characteristics and in motor abilities of strength, of repetition speed in upper limbs, of sprint 10 m. and of agility.

Franchini et al. (2005) conducted a study to verify the differences between elite (Brazilian National and International medalists) and non-elite (non-medalists in Brazilian National Tournaments) junior and senior judo players. The following tests and measurements: skinfold thickness, circumferences, breadths, upper body Wingate test, special judo fitness test, aerobic power and capacity, lactate after combat during active recovery and passive recovery (rest), isometric hand grip strength were conducted. Results showed that elite group presented better results than non-elite group. Elite judo players presented higher upper body and specific anaerobic power and capacity, higher circumferences (specially from upper body, indicating superior muscle mass in this area) and that skinfold, hand grip strength and aerobic power and capacity were similar in elite and non-elite judo players.

Gorostiaga et al. (2005) conducted a study to compare the physical characteristics like body height, body mass, body fat, and free fatty mass, one repetition maximum bench-press, jumping explosive strength, handball throwing velocity, power-load relationship of the leg and arm extensor muscles, 5m and 15m sprint running time, and running endurance in two handball male teams: elite team and amateur team. Elite team had similar values in body height, body fat, vertical jump, 5 and 15m sprint running time and running endurance than amateur team. The elite team group gave higher values in body mass, free fatty mass, 1RM (BP), muscle power during bench-press and half squat and throwing velocities at standing and 3-step running actions than the amateur team group. Significant correlations were found in elite team and amateur team between individual values of velocity at 30 % of 1RM (BP) and individual values of ball velocity during a standing throw. Significant correlations were found in elite team, but not in amateur team, between the individual values of velocity during 3-step running throw and the individual values of velocity at 30 % of
IRM (BP) as well as the individual values of power at 100 % of body mass during half-squat actions. It was concluded that more muscular and powerful players are at an advantage in handball. The differences observed in free fatty mass could partly explain the differences observed between groups in absolute maximal strength and muscle power.

Gabbett (2005) evaluated 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 were measured for standard anthropometry, muscular power, speed, agility and estimated maximal aerobic power during the competitive phase of the season were taken, after players had obtained a degree of match fitness. The results of the study demonstrated that few physiological and anthropometric differences were exist among individual playing positions in junior rugby league players, however props were taller, heavier, have greater skinfold thickness, lower speed, agility, and estimated maximal aerobic power than other positional playing groups.

Hatzimanouil et al. (2005) reviewed the literature about somatotype and anthropometric characteristics of known elite athletes in team sports (water polo, handball, volleyball, football, basketball) and also to clarify the relation between these characteristics and athletic performance. The research findings showed that the athletes’ somatotype and anthropometric characteristics are related to the type of each sport. In addition there was a relation between high athletic performance and physical characteristics like high height, low percentage of body fat and high muscle mass.

Slater et al. (2005) assessed the physique traits and their relationship to competitive success amongst lightweight rowers. Anthropometric measurements were assessed on 107 lightweight rowers (65 males and 45 females). The relationship between physique traits and competitive success was determined. Results showed that lower body fat, greater total body mass and muscle mass were associated with faster 2000 m heat times. It was concluded that the more successful lightweight rowers were those who had lower body fat and greater total muscle mass.

Sallet et al. (2005) evaluated the physical and physiological characteristics of professional basketball players and related them to playing position and level of play. The results showed that centres were significantly taller and heavier than forward and
guards and also had higher body fat percentage than the other groups. Forwards were also significantly taller than guards. Many physical differences, most notably size, exist between players as a function of their playing position, but these differences had no relationship to the level of play of professional players.

Bayios et al. (2006) conducted a study to determine the anthropometric profile, body composition and somatotype of elite Greek female basketball, volleyball and handball players, and compared the mean scores among sports and also to find possible differences in relation to competition level. A total of 518 female athletes, all members of the Greek First National League (A1 and A2 division) in basketball, volleyball and handball sport teams participated in the study. Volleyball players were the tallest among the three groups of athletes, had the lowest values of body fat and their somatotype was characterized as balanced endomorph. Basketball players were taller and leaner than handball players, with a somatotype characterized as mesomorph-endomorph. Handball players were the shortest of all and had the highest percentage of body fat and their somatotype was mesomorph-endomorph. In comparison with their A2 counterparts the A1 division players were taller and heavier, but at the same time leaner, and exhibited higher homogeneity in somatotype characteristics. It was concluded that anthropometric, body composition and somatotype variables of Greek female elite team ball players varied among sports.

Khanna and Manna (2006) conducted a study to evaluate the morphological, physiological and biochemical characteristics of Indian national boxers and to assess the cardiovascular adaptation. Two different studies were conducted. In the first study different morphological, physiological and biochemical parameters of 30 junior boxers below 19 yrs, 30 senior boxers 20-25 yrs were measured. In the second study cardiovascular responses of 21 light Weight category <54 kg, 7 Medium weight category <64 kg, and 7 Medium heavy weight category <75 kg, were studied. Results showed a significantly higher stature, body mass, lean body mass, body fat and strength of back and grip in senior boxers compared to juniors. The senior boxers possessed mesomorphic body conformation whereas the juniors’ possessed ectomorphic body conformation. Significantly lower aerobic capacity and anaerobic power were measured in junior boxers compared to seniors. Significantly higher maximal heart rates and recovery heart rates were observed in the seniors as
compared to the juniors. Significantly higher maximum heart rates were noted during actual boxing compared to graded exercise. The senior boxers showed a significantly high hemoglobin, blood urea, uric acid and peak lactate as compared to junior boxers. The age and level of training in boxing has significant effect on aerobic and anaerobic component.

Ostojic et al. (2006) carried a study to describe structural and functional characteristics of elite Serbian basketball players and to evaluate whether players in different positional roles have different physical and physiological profiles. Five men's basketball teams participated in the study and competed in the professional First National League. Physiological measurements were taken of 60 players during the final week of their preparatory training for competition. According to positional roles, players were categorized as guards, forwards, and centers. Guards were older and more experienced as compared with both forwards and centers. Centers were taller and heavier than guards and forwards, whereas forwards had significantly higher height and weight than guards. Centers had more body fat as compared both forwards and guards. Also, centers had significantly lower estimated VO$_{2\text{max}}$ values compared with forwards and guards. Vertical jump power was significantly higher in centers as compared with guards.

Gabbett et al. (2007) investigated the physiological, anthropometric and skill characteristics of rugby league players and determined the relationship between physical fitness and playing ability in rugby league players. Eighty-six rugby league players underwent measurements of standard anthropometry (height, body mass, and sum of 4 skinfolds), muscular power (vertical jump), speed (10, 20, and 40m sprint), agility (L run), and estimated maximal aerobic power (multistage fitness test). First-grade players had significantly greater basic passing and ball-carrying ability and superior skills under fatigue, tackling and defensive skills, and evasion skills than second-grade and third-grade players. While no significant differences were detected among playing levels for body mass, skinfold thickness, height, 10, 20, or 40m speed, agility, vertical jump height and estimated maximal aerobic power, all the physiological and anthropometric characteristics were significantly associated with at least 1 measure of playing ability.
Mariko et al. (2007) evaluated 6 handball players, 7 basketball players and 8 volleyball players age between 19 to 22 years from university of Japan. Results of the study showed that the difference in girth of upper arm, skinfold thickness of upper arm and percentage of body fat among 3 ball game teams were statistically significant. The girth of upper arm of the handball players was significantly higher than that of basketball players, and the skinfold thickness of upper arm and percentage fat was significantly lower in handball players than in volleyball players. The volleyball players were the tallest and the basketball players were shortest.

Vaghetto et al. (2007) conducted a study on 103 surfers, 42 professional male athletes, 11 professional female athletes, 25 amateur college student athletes and 25 surf practitioners. The auditory and visual single reaction span in surfers with different ability levels of comparison of professional, amateur athletes and surf practitioners were identified. Auditory and visual reaction span in professional and amateur surfers as well as surf practitioners have statistical differences among the surfers groups as well as to correlate the reaction span with the athletes' performance. Statistically significant differences were found for the auditory and visual reaction span between the professional male versus practitioners and professional female versus practitioners. Statistically significant differences were found between the amateurs versus practitioners only for the visual reaction span, with lower reaction span for the more experienced ones. A positive correlation was found for the visual reaction span between the professional female athletes versus the ranking.

Young and Pryor (2007) conducted a study to know the relationship between selected anthropometric and fitness measures with indicators of performance in elite junior Australian football players. 485 players from the elite Victorian under-18 Australian rules football competition were evaluated for height, body mass, hand span, arm length, standing reach, vertical jump, 5 and 20 m sprint times, agility, predicted VO$_{2\text{max}}$, and sit and reach flexibility. There were several significant differences between selected and non-selected players observed. Players acquiring the most possessions were significantly shorter with less body mass and possessed greater acceleration and endurance. Body mass was significantly related to the number of marks and height was related to hit outs. Acceleration was the only fitness quality to discriminate between higher and lower vote winners. The players from the top four
teams had a significantly greater standing reach, were heavier but not superior in any fitness measure.

**Veale et al. (2008)** undertook a study on 54 players, who were selected for a Victorian elite junior U-18 Australian rules football squad. Anthropometric and physical performance of players was measured using a battery of standard tests. Results showed differences between selected and non-selected players when height, weight, 20m sprints, agility and vertical jump height were considered collectively. Findings revealed that the vertical jump was the only significant individual test and a near significant trend for height differentiating between selected and non-selected players with medium effect sizes for all other tests except endurance.

**Campos et al. (2009)** conducted a study on 20 athletes (10 male athletes and 10 female) of Brazilian junior badminton team for assessing the anthropometric profile and motor performance of young badminton athletes. Anthropometric measurements body weight, height, bone diameters of humeral and femoral, circumferences of relaxed arm, contracted arm, thigh, calf, and skinfold thicknesses of triceps, subscapular, suprailiac, abdominal, biceps, thigh and calf were taken of all the subjects. The results showed that significant differences were found between genders after comparing the following variables: age, height, sum of seven skinfolds, contracted biceps circumference, humeral and femoral breadth and also show up that there were no significant differences in body weight and lower limbs circumferences of thigh and calf found. Vertical jump test results showed that there were significant differences between genders in the three types of vertical jumps. The results of this study described anthropometric and motor test characteristics of young athletes playing in the Brazilian junior badminton team.

**Chaouachi et al. (2009)** tested twenty-one players of international handball team according to their playing positions. Anthropometric, physiological and performance characteristics were measured. The height, body mass, percentage body fat and endurance, performance measures of speed, strength, unilateral and bilateral horizontal jumping ability and a 5 jump horizontal tests were conducted. Significant differences were found between player positions for some anthropometric characteristics but not for the physiological or performance characteristics. It was
concluded that performance abilities between positions in elite team-handball players appear to be very similar.

**Gabbett et al. (2009)** investigated physiological and anthropometric characteristics of junior elite and sub-elite rugby league players. Thirty-six junior sub-elite and 28 junior elite rugby league players participated in this study. Subjects underwent measurements of anthropometry, speed, change of direction speed, estimated lower body power, and estimated maximal aerobic power at the beginning of the competitive season. Elite players had better developed speed, change of direction speed, estimated lower body power, and maximal aerobic power than sub-elite players.

**Joksimovic et al. (2009)** examined 368 football players who were participating in the 2008 European Football Championship. The objective of this research was to define the average values for all players by analyzing basic anthropomorphological parameters, as well as certain body indices. The study showed that the height of all the participants in the 2008 European Football Championship was 182.97 ± 6.59cm and the average body mass 77.88 ± 6.98kg. The tallest average was noted in goalkeepers, followed by defense and forward players, while the lowest value for height (179.02 ± 5.94cm) and body mass (73.89 ± 5.81) were noted in the midfield players. They further stated that apart from forwards each particular position requires a particular body type.

**Nande et al. (2009)** conducted a study to assess anthropometric profile of 13 female and 46 male trained players who engaged in different sports disciplines. The measurements taken body weight, standing height, mid upper arm circumference, chest circumference, waist circumference, hip circumference, thigh circumference, calf circumference, shoulder width and body mass index were taken of the subjects. Results showed that all players were found to be shorter than their respective standard heights. Less than 50 % groups of male players were found meeting the desirable body weight standards between height & weight. Positive correlations were derived for majority of sport groups of female & male players. Body weight was found to be directly proportional to shoulder width with positive correlation. Body mass index revealed stronger correlation with weight than height.
Pelin et al. (2009) tested 27 American footballers, 26 volleyballers, 31 basketballers, 34 footballers and 35 young non-players of Turkish. The physical characteristics of athletes were evaluated and compared to each other and to those of non-players. 17 anthropometric values, body mass index and somatotype components were calculated and evaluated. The result showed that basketball and volleyball players were characteristic with their longer lower limb length, American footballers were with their wider biiliiac breadth and higher girth values and footballers with their small structure. It was also observed that Turkish players have higher endomorphy and lower mesomorphy values when compared to players from other countries.

Tan et al. (2009) conducted a study of the anthropometric and fitness characteristics of elite female water polo players and examine the differences between players of different competition levels (national and international) and playing positions (center and perimeter). Twenty-six female water polo players were assessed for standard anthropometry (height, body mass, and sum of 7 skinfolds), lower-body muscular power (in-water vertical jump), speed (10-m maximal sprint swim), and aerobic fitness (multistage shuttle swim test). The National squad players were taller and heavier and had better jumping, sprinting, and endurance swimming abilities compared with the National League players. Perimeter players had lower-body mass and skinfold levels and better sprinting and endurance swimming abilities compared with center players.

Wong et al. (2009) studied a relationship between anthropometric and physiological performances among youth soccer players and the positional differences for these variables. Seventy U-14 male soccer players participated in the study. Body mass was significantly correlated with ball shooting speed and 30m sprint time. Body height was significantly correlated with vertical jump height, 10m and 30m sprint times, Yo-Yo intermittent endurance run distance and running time during maximal oxygen uptake. Body mass index was significantly correlated with ball shooting speed, 30 m sprint time, Hoff test dribble distance, Yo-Yo intermittent endurance run distance, sub maximal running cost, VO_{2\text{max}} and the corresponding running time. Significant positional differences were observed in anthropometry body mass, height and body mass index but not in physiological performances.
Ziv and Lidor (2009) reviewed a series of studies (n-23) on physical characteristics, physiological attributes, throwing velocity and accuracy, and on-court performances of male handball players, amateur players, experienced players, professional players, and players on the national team. Five main findings emerged from our review: (1) Elite players were heavier and have higher fat-free mass than amateur players. (2) The maximal oxygen uptake of male players was between 50 and 60 ml _ kg_1 _min_1. (3) Throwing velocity was higher by as much as 9% in elite male players compared with amateur male players. (4) Heart rates can rise above 160 beats _min_1 in male players during a game. (5) On-court distance covered in a game averaged approximately 4 km and ranged between 2 and 5 km, depending on playing position.

Dupler et al. (2010) examined the physical and performance differences between grade levels and playing positions within high-school football players. Two thousand three hundred and twenty-seven athletes were tested for height, weight, 40-yd sprint time, pro agility time and vertical jump height. The results indicated that defensive players in the 11th and 12th grades were significantly faster in the 40yd sprint, quicker in the pro agility and generated more power than 9th and 10th grade defensive players across all positions. Similarly, offensive players in the 11th and 12th grades were significantly faster, quicker, and jumped higher than did football players in lower grades.

Erculj et al. (2010) conducted a study to determine and analyze the level of certain motor abilities of young elite European female basketball players and also establish whether there were any differences between three groups of female basketball players who differed in terms of their playing performance. Sixty five female basketball players from A, B, and C divisions of the European were evaluated. Groups were compared by using 8 motor tests. It was concluded that the division C players achieved below-average in all tests and thus differ from the players from divisions A and B whose test results were relatively homogeneous. The division C players differ from those from divisions A and B mainly in the 6 × 5m sprint dribble. Discriminatory power in the 6 × 5m sprint dribble and 20m sprint tests was preserved even after eliminating the effect of body height.

Gabbett et al. (2010) investigated the tackling ability of junior elite and sub elite rugby league players and determined the relationship between selected physiological
and anthropometric characteristics. Twenty-eight junior elite and 13 junior sub-elite rugby league players underwent a standardized 1-on-1 tackling drill in a 10m grid. Junior elite players had significantly greater tackling proficiency than junior sub-elite players. Junior elite players tended to be taller, heavier and leaner and have greater acceleration, change of direction speed and muscular power, than the junior sub-elite players. The strongest individual correlates of tackling ability were acceleration and lower body muscular power.

Hazir (2010) examined 305 professional male soccer players of Turkish Super League and Turkish First League. Height, weight, flexed and tensed upper arm and calf girths, humerus and femur biepicondylar breadths, and four skinfold thicknesses (triceps, subscapular, supraspinale, and medial calf) were measured. Somatotypes were estimated using the Heath-Carter method. The results of the study demonstrated that both physical characteristics and somatotype of players were significantly different between playing levels and positions. Although the somatotype of soccer players in both levels was dominated by the mesomorph category, players at the higher playing level were more mesomorphic, and less endomorphic and ectomorphic than players at the lower level at all playing positions.

Koley and Kashyap (2010) conducted a study on 56 Indian inter-university female cricketers from six Indian universities. 101 controls were also studied. Fifteen anthropometric characteristics were measured. Results indicated the significant differences between Indian inter-university female cricketers and controls in subscapular skinfold, suprailiac skinfold, calf skinfold and thigh circumference. Weight has significantly positive correlations with all the variables studied (except height and biceps skinfold), for all the five skinfold measurements, significant positive correlations were found with the entire variable studied except height and humerus bi-epicondylar diameter. Similarly, for all the six circumferential measurements, significantly positive correlations were noted with all the variables studied except height.

Koley and Singh (2010) assessed eleven anthropometric characteristics, four body composition parameters, two physical and two physiological variables of sixty (35 males and 25 females) inter-university Indian basketball players aged 18-25 years. Eleven anthropometric variables height, weight, body mass index, chest
circumference, hip circumference, femur biepicondylar diameter, humerus biepicondylar diameter, biceps skinfold, triceps skinfold, subscapular skinfold and calf skinfold, four body composition parameters percent body fat, percent lean body mass, basal metabolic rate and water percent, two physical parameters right and left hand grip strength and two physiological variable heart rate and VO$_2$max were taken on each subject. The results indicated that male basketball players were taller and heavier and female basketball players were slightly taller and lighter than their control counterparts. It showed significant between group differences in all the variables (except hip circumference) between basketball players and controls.

Nimphius et al. (2010) carried out a study to assess the relationship between strength, power, speed and change of direction performance of female softball players. Ten female softball players from a state Australian institute of sport softball team were tested for maximal lower body strength, peak force, peak velocity and peak power during jump squats unloaded and loaded, unloaded countermovement vertical jump height 1 base and 2 base sprint performance and change of direction performance on dominant and non dominant sides. The testing sessions occurred pre, mid and post a 20-week training period. Relationship between body weights, relative strength, vertical jump height, relative peak power, relative peak force, peak velocity, speed, and change of direction variables were assessed by Pearson product-moment correlation coefficient at each testing session. Significant relationships were found across all time points with body weights, speed, and change of direction measures and relative strength and measures of speed and change of direction ability. There were no significant relationships between vertical jump height and any measure of performance at any time point. It was concluded that body weights and relative strength have strong to very strong correlations with speed and change of direction ability and these correlations remain consistent over the course of the season.

Mirkov et al. (2010) conducted a longitudinal study to explore the anthropometric and physical performance characteristics of young soccer players between the age of 11 and 14 and also to reveal the performance at the age of 11. Male players of the best national male squads of the 'cadet league' were annually tested starting from the age of 11 for body size and composition, flexibility, power, coordination, and agility. Randomly selected untrained but physically active age-matched boys were also tested.
over 4 consecutive years. It was found that no difference between two groups regarding the body size and composition. The differences in flexibility emerged only at the later age, while the differences regarding the explosive power were moderate and partly inconsistent. The most prominent advantage of the soccer players over the control subjects during the entire tested age period appeared to be movement agility and coordination. So the explosive muscle power, the agility and coordination characterize elite soccer players of 11-14 years of age but not the body size and body composition.

**Orhan et al. (2010)** carried out a study on twenty four football players from turkcell Turkish super league on the basis of the player’s positions. The anthropometrical measurements: triceps, subscapular, supraspinale measurements and the calf and skinfold thickness, humerus bicondylar diameter, femur bicondylar diameter, biceps girth, weight, and height measurements were analyzed for the study. The result showed that there were no significant differences in the different positions among the team players.

**Singh et al. (2010)** conducted a study on fifty three field hockey players to determine the anthropometric measurements and body composition of teams from India, Pakistan and Sri Lanka. The participants were assessed for height, weight, widths and diameters, girths and lengths, grip strength and skinfold thickness. The percentage of fat was calculated from the sum of 4 measurements of skinfold thickness. It was found that there were no significant differences in height and weight among the three teams. The Pakistan team had a significantly higher upper arm length and bi-humerus diameter as compared to the India and the Sri Lanka teams. The Sri Lanka team had significantly less wrist circumference, hand width and lean body mass as compared to the India and the Pakistan teams. The India team had significantly less % body fat than the other two teams.

**Singh et al. (2010)** conducted a study to find out anthropometric measurements, body composition and somatotyping differences in high performer and low performer high jumpers. 20 male university level high jumpers (10 high performers and 10 low performers) of age 18 to 25 years were assessed for the present study during the All India Inter University Athletic Meet. All subjects were assessed for height, weight, breadths, girths and skinfold thickness. Percentage of fat was calculated from the sum
of 4 measurements of skinfold thickness. The results showed that high performer high
jumpers had significantly higher height, weight, body mass index, total leg length,
total arm length as compared to low performer high jumpers. The high performer high
jumpers also had significantly greater all three circumferences, bi-humerus and bi-
femur diameters, lean body mass and mesomorphic score as compared to low
performers whereas the low performer high jumpers were found to have significantly
higher % body fat and endomorphic score than the high performers.

Siahkouhian and Hedayatneja (2010) evaluated the correlations of anthropometric
and body composition variables with the performance of Iranian elite weightlifters.
Forty two subjects evaluated. Anthropometric and body composition variables, as
well as performance of weightlifters (i.e., snatch; clean & jerk; front squat; back
squat) were measured. Results showed that the snatch and clean & jerk records
significantly correlated with height, sitting height, weight, shoulder and chest
circumference, lean body mass, body mass index; whereas we showed negative
correlations between the snatch and clean & jerk records with the %fat as well as
WHR values. Results also showed that the snatch and clean & jerk records
significantly correlated with body mass index. It was concluded that there were strong
correlations existing between weightlifter performance and the anthropometric and
body composition variables.

Comfort et al. (2011) conducted a study to compare the strength and power
characteristics of forwards and backs in a squad of elite English rugby league players.
Testing included 5, 10, 20m sprint times, agility, vertical jump, 40kg squat jump,
isometric squat, concentric and eccentric isokinetic knee flexion and extension.
Independent samples t-tests were performed to compare results between forwards and
backs, with paired samples t-tests used to compare bilateral differences from
isokinetic assessments and agility tests. Forwards demonstrated significantly greater
body mass, height, power during the 40kg jump squat, isometric force and peak
torque during left concentric isokinetic knee extension compared to the backs. Also
no significant differences were noted between forwards and backs during right
concentric isokinetic knee extension, concentric isokinetic knee flexion for both left
and right legs, eccentric isokinetic knee flexion and extension, hamstring quadriceps
ratios and vertical jump. In comparison, relative measures demonstrated that backs
performed significantly better compared to the forwards during the 40kg jump squat and the isometric squat. Bilateral comparisons revealed no significant difference between left and right leg performances in the agility test and between left and right leg eccentric hamstring concentric quadriceps ratios. It was concluded that absolute strength and power measures are generally higher in forwards compared to in backs.

Gaurav et al. (2011) conducted a study to compare the physical fitness variables among baseball players at different level of achievement. The subjects for the study were 15 district level and 15 state level male baseball players from Punjab. All the players were assessed for physical fitness components such as speed, strength and power. Results revealed that state level baseball players had significantly higher speed, strength and power than district level baseball players.

Gaurav et al. (2011) conducted a study to compare the arm and shoulder girdle strength and agility of college level female baseball pitchers and non-pitchers. Twenty four randomly selected female baseball players of different colleges affiliated to Guru Nanak Dev University, Amritsar, volunteered to participate in the study. Out of 24 female baseball players 12 were pitchers and 12 were non-pitchers. Medicine ball put test was used to measure the arm and shoulder girdle strength whereas Illinois Agility Test was used to measure running agility of the subjects. The independent samples t-test reveals that pitchers had significantly greater arm and shoulder girdle strength as compared to non-pitchers. In case of agility, there was no significant difference between pitchers and non-pitchers.

Karalejic et al. (2011) evaluated 118 young basketball players, 54 of 14 year old and 64 of 12 year old. 18 anthropometric variables: five longitudinal measures, two transversal measures, body mass, four circumferences, six skinfolds and 3 derived variables: body mass index, sitting height/stature ratio and sum of skinfolds were measured. Four basketball field tests: speed spot shooting, passing, control dribble and defensive movement were conducted. Results showed that the values of most of anthropometric variables were significantly higher in 14 year old players as compared to 12 year old, except in sitting height/stature ratio and body mass index which were similar. Only values of sum of skinfolds were significantly lower in 14 year old players. In variables: control dribble, passing and defensive movement 14 year old players have better scores than 12 year old players.
Nilkbkht (2011) investigated relation between anthropometrics and body type endomorph, mesomorph and ectomorph with factors aerobic fitness, speed and power of 45 untrained male students of Tehran University. The physical fitness factor was measured through a special related method designed by Heath, Carter and Seldon. Physical fitness tests included: running in 60 meter, vertical jump, board jump, medicine ball throw and Harvard step test. Results indicated that there were meaningful relationships between ectomorph component and aerobic fitness. The relationship between body fat, body weight and aerobic fitness was negative; The relationship between body weight and feet power, hand power was negative. The relationships between skin fold fat, foot power and body’s general speed were considered being as negative. Finally the relationship between girth arm and hand power was considered being as meaningful.

Scanlan and Dascombe (2011) examined thirty three male and thirty female high-performance life savers. Anthropometric measurements included stature, mass and arm span, whilst the performance measures taken were vertical jump height, 5 m and 20 m sprint times, maximal velocity, hamstring flexibility, agility, maximal aerobic capacity, and chest, back and leg strength. Results revealed significant gender differences for stature, arm span, vertical jump height, 20 m sprint time, hamstring flexibility, agility, maximal aerobic capacity and back and leg strength.

Singh et al. (2011) carried a study to find out anthropometric measurements, body composition and somatotyping differences in high performer and low performer hammer throwers. 20 male hammer throwers (10 high performers and 10 low performers: 10) of age 18 to 25 years were assessed for the study. All subjects were assessed for height, weight, widths, girths and skinfold thicknesses. The independent samples t-test revealed that high performer hammer throwers had significantly higher weight, sitting height, body mass index and lower leg length as compared to low performers. The high performer hammer throwers were also found to have significantly greater all circumferences and skinfold measurements. High performers hammer throwers also had significantly higher % body fat, total body fat and lean body mass as compared to low performers. Endomorphy and mesomorphy were significantly higher in high performer hammer throwers whereas ectomorphy was significantly greater among low performers. It was concluded that in most of the
parameters there were significant differences between high performer hammer throwers and low performer hammer throwers.

2.2 STUDIES RELATED TO VOLLEYBALL GAME

Spence et al. (1980) analyzed 15 members of the United States Women's National Volleyball Training Team. Data were obtained from anthropometric, strength, physiologic and motor performance domains. Within-group comparisons were made between the six women who were selected for the Pan-American Team and the nine who were not. The Pan-American selectees were taller, heavier and demonstrated greater motor ability than the non-selectees. Strength measurements did not indicate consistent differences between the two sub-groups. The non-selected players had a greater VO$_{2\text{max}}$ than those selected. Between-group comparisons on selected variables were made between the subject and other American women volleyball players. The training team subjects were taller and heavier than the comparative groups. The training team group demonstrated lower heart rate MAX (180 beats/min) than the other groups reported, and their VO$_{2\text{max}}$ (43.2 ml/kg/min) was within the range of the comparative groups.

Puhl et al. (1982) evaluated the absolute relative physical and physiological characteristics of elite men and women volleyball players. The total 22 volleyball players (8 male and 14 female) were investigated and findings of the investigation showed that the male volleyball players were taller, heavier and had a higher body density, lean body weight and low fat. The differences in the muscle mass between male and female volleyball players were apparently due to sex differences.

Devi (1985) evaluated twenty-four volleyball players to find out the relationship of selected strength and flexibility measures to playing ability in volleyball. The findings of her study concluded that arm strength, abdominal strength was significantly related to playing ability in volleyball. Grip strength did not correlate significantly to playing ability in volleyball. Wrist flexibility and ankle flexibility had insignificant relationship to playing ability in volleyball. Trunk flexibility showed negative but insignificant correlation to playing ability in volleyball.

Fleck et al. (1985) examined the 1980 U.S. Women's National Volleyball Team and the collegiate players who composed the 1979 U.S. Women's University Games
Volleyball Team. The characteristics compared were age, height, weight, body composition determined via hydrostatic weighing, vertical jumping distance, vertical jumping height, maximal oxygen consumption, heart rate max and respiratory exchange ratio. Significant differences in age, percent of body fat, and vertical jumping distance between the two teams were demonstrated, with the National Team being significantly older, having a lower percentage of body fat and possessing a larger vertical jumping distance.

Hascelik et al. (1989) analyzed twenty male volleyball players during an 8-week-period. They did physical conditioning exercises by weight training 5 days a week. Physical fitness tests, auditory and visual reaction times were measured at the beginning and at the end of training period. Results showed that physical conditioning exercises affected their physical fitness positively and moreover auditory and visual reaction times were shortened.

Rawat (1989) conducted a study to determine the physical, physiological and motor skill variables of male volleyball players, which could best contribute in the playing ability of volleyball players. He found that explosive power, agility and ankle flexibility were main contribution for the volleyball playing ability and out of 7 physiological variables, cardiovascular endurance, lean body weight and pulse pressure were contributors and of the 4 motor skill variables, volleying and serving were the best contribution for volleyball playing ability.

Sodhi et al. (1990) evaluated 287 volleyball players and 196 non-volleyball players of 14 to 16 years of age group. The height, sitting height and hand span of subjects were measured. It was observed that these variables gradually increased with the age. In volleyball players hand size also increases with age. They also investigated that taller height with longer legs and arms and greater hand span were helpful in the game of volleyball.

Thissen-Milder and Mayhew (1991) examined fifty high school volleyball players during the first week of practice for six general and four specific motor performance tests. The specific tests included the overhead volley, forearm pass, wall spike, and self bump/set test. The general tests included height, weight, percent body fat, agility run, vertical jump, and two flexibility maneuvers. Varsity players were significantly better in vertical jump, agility, and all specific ball-handling tests than freshmen and
junior varsity players. The combination of forearm pass, overhead volley, vertical jump, and weight correctly classified 68% of the players to their team level. The combination of bump-set, height, weight, and shoulder flexibility allowed correct classification of 78% of the starters and nonstarters.

Smith et al. (1992) investigated physical, physiological and performance characteristics from fifteen players of Canadian national team and twenty four volleyball players of university teams. The parameters examined were percent body fat, maximal oxygen uptake, anaerobic power, bench press, 20-m sprint time and vertical jumping ability. It was found that there was significant difference in physical characteristics between the two teams. The national team players had significantly higher block and spike jumps as well as 20-m sprint time and also the high VO$_{2\text{max}}$ value.

Hakkinen (1993) conducted a study on nine female volleyball players in order to examine changes in a physical fitness profile during the competitive season consisting of a first season for 10 weeks followed by second season 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 findings of the study showed that the entire competitive season in subjects led to no changes in VO$_{2\text{max}}$ but a significant decrease took place in average power in a 30s anaerobic jumping test. Significant increases took place in the maximal vertical jumping heights in the squat and in the counter movement jump as well as in the spike and block jumps during competitive season.

Singh (2000) conducted a study to know the relationship between physical characteristics, motor ability and motor skill variables of male volleyball players. He concluded that the height, flexibility, wrist flexion, wrist extension, trunk hyperextension, speed, arm strength, leg explosive power, dynamic balance and agility were the main contributor for the volleyball playing ability.

Guladi-Russo and Zaccagni (2001) tested two hundred and thirty-four male athletes and two hundred and forty-four female athletes from the Italian A1 and A2 volleyball leagues for anthropometric measurements during the 1992-1993 and 1993-1994 seasons. Somatotypes were estimated with the Heath-Carter method. Marked sexual dimorphism in somatotype was observed in the total sample. The somatotype was
significantly different in players at different levels of performance. The somatotype was also significantly different in players in different roles. It was concluded that the physique of athletes in the A1 league was characterized by higher ectomorphy and lower endomorphy and mesomorphy. There was also a slight tendency of male players to a greater homogeneity in somatotype within the group at the maximum level of performance. Moreover somatotype differs in relation to game role in volleyball players of both sexes: the mesomorphic component was maximal in setters, while the ectomorphic component was maximal in centres.

Tsunawake et al. (2003) carried out a study on 12 members of the women's volleyball team and 11 members of the women's basketball team that won the championship in the Japan Inter-high school meeting. They examined the differences in the physical abilities, the body composition between the members of the top teams of different events. It was noticed that there was no significant difference in physique, skinfold thickness and body composition between the volleyball players and basketball players.

Marques et al. (2004) tested 11 elite male top volleyball players submitted to a 12-week strength training program apart from normal technical/tactical practice sessions (3-4 hours per day) and competitions. The overall sample was tested on 2 occasions for maximum strength (bench press and half squat) and explosive strength (jumping and throwing). The first testing session was completed at the end of a preparatory period strength training (5 weeks) to ensure that all athletes would be in a state of good overall condition. The results suggest that elite top volleyball players were optimized their performance over 12 weeks of strength training during the competition season.

Stamm (2004) analyzed the body structure of 46 female volleyball players. 49 body measurements, including 11 skinfolds and 9 physical fitness tests, 9 volleyball technical tests and 21 psycho-physiological tests were applied. In parallel, 32 player’s performances at competitions were registered by an original volleyball recording program titled the game, and body structure and test results were correlated with proficiency in the game. The structure of the body implies that very different body measurements can be applied in volleyball research, and correlation analysis should help to establish which body measurements are essential for the task studied. The tests
showed a correlation with body structure, between them, and were essential for assessing proficiency in the game. Thus, by means of a regression model consisting of 14 anthropometric variables, it was possible to predict the girls’ proficiency in performing the serve, reception, block and attack within 32–83%; 4 physical ability tests were essential in reception, block and attack. Psycho-physiological models were essential for reception, feint and attack. Volleyball technical models were essential in the efficiency of reception within 32% and feint within 44%.

**Chauhan and Chauhan (2005)** conducted a study on 40 college level volleyball players of Kurukshetra University. They tested various body measurements i.e. height, sitting height, trunk length, upper and forearm length, foot length and circumference of chest, abdomen, hip, thigh and diameter of biacromial, bitrochantric, femur bicondylar and skinfolds of biceps, triceps, subscapular, suprailliac and mid axillary. It is necessary to have strong arm for volleyball players to perform skills such as blocking, smashing, serving and receiving, so the objective of this study was to know the relationship between anthropometric variables and explosive arm strength. The results showed that anthropometric variables have positive and significant correlations with arm strength of volleyball players. It was concluded that multiple correlation of height, biacromial, elbow diameter, lean body mass taken together with explosive arm strength have been found significantly at 1% level. The size of the multiple correlations was sufficiently large and hence regression equation developed is useful for the prediction of the explosive arm strength.

**Gonzalez et al. (2005)** conducted a study to determine the intensity of effort in competition of the liberos and central players by measuring heart rate and blood lactate. 30 players from 10 teams were selected as subject. Heart rate was measured by telemetry during the matches. Blood samples were obtained when there were substitutions for the players. Results indicated significant differences in mean and maximal heart rate values between the central players and the liberos. Mean and maximal heart rate values tended to decrease in the last sets in all the positions analyzed. With regard to blood lactate, significant differences were observed in mean values between the two central players and the liberos.

**Kasabalis et al. (2005)** evaluated the anaerobic power of elite male volleyball players, using the Wingate Anaerobic Test to examine the relationship between
anaerobic power and jumping performance. Athletes and non-athletes were divided into three age groups: adults, juniors and youth. Measurements of height, body mass, vertical jump and Wingate scores indicated higher values for athletes. The specific training effects of anaerobic power for athletes were more pronounced at the age of 10-11 years than for non-athletes. A significant correlation coefficient between peak power and vertical jump was found for athletes and for the total group. These results indicated that vertical jump may predict the maximal anaerobic power and could be used by coaches as a practical and easy-to-apply field screening test for evaluation in volleyball training.

Duncan et al. (2006) investigated the anthropometric and physiological characteristics of junior elite volleyball players. Twenty five national level volleyball players were assessed on a number of physiological and anthropometric variables. Somatotype was assessed using the Heath-Carter method, body composition was assessed using surface anthropometry, leg strength was assessed using a leg and back dynamometer, low back and hamstring flexibility was assessed using the sit and reach test, and the vertical jump was used as a measure of lower body power. Maximal oxygen uptake was predicted using the 20 m multistage fitness test. Results of the study showed that the setters were more ectomorphic and less mesomorphic than centres. Hitters had significantly greater low back and hamstring flexibility than opposites. There were no other significant differences in physiological and anthropometric variables across playing positions.

Gabbett et al. (2006) investigated the effect of a skill-based training program on measurements of skill and physical fitness in talent-identified volleyball players. Twenty-six talented junior volleyball players participated in an 8-week skill-based training program that included 3 skill-based court sessions per week. Skills sessions were designed to develop passing, setting, serving, spiking, and blocking technique and accuracy as well as game tactics and positioning skills. Subjects performed measurements of skill (passing, setting, serving, and spiking technique and accuracy), standard anthropometry (height, standing-reach height, body mass, and sum of 7 skin folds), lower-body muscular power (vertical jump, spike jump), upper-body muscular power (overhead medicine-ball throw), speed (5- and 10-m sprint), agility (T-test), and maximal aerobic power (multistage fitness test) before and after training. Training
induced significant improvements in spiking, setting, and passing accuracy and spiking and passing technique. Compared with pre training, there were significant improvements in 5- and 10-m speed and agility. There were no significant differences between pre training and post training for body mass, skinfold thickness, lower-body muscular power, upper-body muscular power, and maximal aerobic power.

Grgantov et al. (2006) evaluated 246 female volleyball players divided into four age groups: 32 players aged 12–13, 147 players aged 14–15, 50 players aged 16–17, and 17 players aged 18–19. The quality of performance was assessed as a criterion variable. Results showed the female volleyball players of various age groups to differ significantly according to the variables assessing the longitudinal skeleton dimensionality, and body mass and volume, as well as in all tests used on volleyball technique evaluation. Analysis of variance within particular age groups additionally clarified the process of modification in all studied variables.

Bandyopadhyay (2007) tested 82 volleyball players and 45 football players and 50 sedentary males from West Bengal of 20-24 years of age. He evaluated and compared anthropometry and body composition, skinfolds, circumference, body fat percentage and endomorphy. All players were significantly higher among sedentary persons, lean body mass and mesomorphy were significantly higher among the sports persons. Football and volleyball players were found to be ectomorphic mesomorph whereas sedentary persons were endomorphic mesomorph. All the skinfolds and calf girths were significantly higher in the sedentary group, indicating that the sedentary population has a greater quality of subcutaneous fat deposition which was also reflected in their significantly higher value of percentage fat than the sports persons.

Barnes et al. (2007) conducted a study to examine the jumping and agility performance between National Collegiate Athletic Association Division I, II, and III athletes. Twenty-nine collegiate female volleyball players completed a novel agility test, countermovement and drop jump tests, and an isometric leg extensor test. One-way analysis of variance revealed that Division I athletes had significantly greater countermovement jump heights than Division III, and the effect size comparisons showed large-magnitude differences between Division I and both Divisions II and III for jump height. No other differences in performance variables were noted between divisions, even though effect sizes reached moderate values for some comparisons.
Regression analysis revealed that countermovement displacement was a significant predictor of agility performance.

**Hespanhol et al. (2007)** tested ten male volleyball players and verified the differences between the continuous jump test of 60 seconds and the intermittent jump test of 4 sets of 15 seconds. The variables studied were estimated as the peak power, mean power and fatigue index. These performances were measured through tests of vertical jump with duration the 60 seconds and with the performance of 4 sets of 15 seconds with 10 seconds of recovery between the sets. Results showed that the continuous and the intermittent jump test presented significant differences in mean power, fatigue index, and in the number of the vertical jumps in 60 seconds, and the height in 60 seconds exercise. The mean power found in intermittent jump test of 4 sets of 15 seconds was significantly higher than in the continuous jump test of 60 seconds in volleyball players.

**Gabbett and Georgieff (2007)** evaluated the physiological and anthropometric characteristics of junior volleyball players. One hundred and fifty-three junior national, state and novice volleyball players were tested. 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 (5m and 10m sprint), agility (T-test), and estimated maximal aerobic power (multistage fitness test) during the competitive phase of the season. Results showed that the significant differences 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, physiological and anthropometric characteristics of players showed improvement 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.

**Lidor et al. (2007)** examined the contribution of a battery of physical and motor tests to early phases of talent detection and early development and secondly to differentiate between and compare the motor ability of 16-year-old starter and non-starter in volleyball. Fifteen male adolescent volleyball players underwent assessment of physical and motor ability tests 6 times during a 15-month training program; however,
not all of them took part in each testing phase. The battery was composed of 8 physical and motor tests and 2 skill tests. The physical and motor tests included 2 speed tests, an agility run, 4 explosive power tests, and an endurance test. The skill tests evaluated service accuracy at rest and following effort. Results indicated that all participants improved their performance in all tests but particularly in two tests i.e. endurance and skill tests across testing phases. Comparisons between the starters and non-starters revealed that only one physical explosive power test (vertical jump with approach), was found to be a good indicator for distinguishing between the 2 groups of players.

Mohan and Sharma (2007) examined 334 volleyball players of Himachal Pradesh. The AAHPER youth fitness test battery, consisting of six test items: pull-ups, sit-ups, standing broad jump, shuttle run, 50 yard dash, and 600 yard run or walk was used to measure the motor fitness level of volleyball players. The findings of the study showed that winner volleyball players are better in almost all motor fitness components, except runners up and winner volleyball players as compared to looser volleyball players.

Batista et al. (2008) conducted a study to compare the anthropometric profile and the vertical jumps of thirty eight male beach volleyball players from the Brazilian Beach Volleyball Circuit. The players were divided into two groups according to national ranking of their teams. The result showed that there was no statistically significant difference in anthropometric profile between the two groups. The players of group one were better in the spike jump, block jump and block difference than the players of group two.

Grigoris et al. (2008) tested 163 elite female volleyball players. The aim of study was to know the morphological characteristics of these competitive female volleyball players. Body weight, height, breadth, girths and skinfold thickness were measured. The results revealed that body height ranged from 161cm to 194cm, the mean value of 177.1 ± 6.5cm was not inferior to that of international players. Adiposity of these players was higher than that of reported in other studies. Elite volleyball players had balanced endomorphs (3.4-2.7-2.9). According to different playing positions significant differences were found among the players which were due to their varying roles and physical demands during the volleyball game.
Luciana et al. (2008) analyzed anthropometric and physiological characteristics of 146 former elite volleyball players in Italy. The possible effect of an active or inactive lifestyle on ageing was assessed by comparing the biological profiles of sub-samples of former athletes with and without regular sport activity. All the former athletes underwent measurements of standard anthropometry (height, sitting height and body mass; skinfold thicknesses; bi-acromial and bi-cristal breadths; upper limb length; upper arm, calf and chest girths), cardio-respiratory function (vital capacity, forced vital capacity, forced expiratory volume in 1sec; systolic and diastolic blood pressures and heart rate), muscle strength (handgrip strength), and cognitive function (visual and auditory simple reaction times; Digit-Symbol subtest). Body composition parameters were estimated from anthropometric measurements. Data on lifestyle were collected by questionnaires. The results showed that the former players differ from current players in several anthropometric and physiological traits.

Rousanoglou et al. (2008) analyzed the muscular strength and vertical jumping performance of young women track and field jumpers and volleyball players. Pearson product-moment coefficient of correlation was used to test the significance of their relationships. The results showed the dissimilarity in the relationships between the knee extensor muscular strength and jumping performance in the young female track and field jumpers and volleyball players.

Sheppard et al. (2008) assessed the relationship of volleyball performance among strength, power and anthropometric variables with counter-movement vertical jump and spike jump, a correlation and regression analysis was performed. In addition, a comparison of strength, power, and anthropometric differences between the seven best subjects and the seven worst athletes on the counter-movement vertical jump test and spike jump test was performed. When expressed as body mass relative measures, moderate correlations were observed between the 1RM measures and both relative counter-movement vertical jump and relative spike jump. Very strong correlations were observed between relative depth jump performance and relative spike jump and relative counter-movement vertical jump. The results of this study clearly demonstrated that in an elite population of volleyball players, stretch-shortening cycle performance and the ability to tolerate high stretch loads, as in the depth jump, was critical to performance in the jumps associated with volleyball performance.
Marques and Marinho (2009) undertook a study of physical parameters and performance values in starters and non-starters volleyball players. 22 professional male volleyball players were selected as subjects and the players were categorized as starters (n= 13) and non-starters (n= 9). Anthropometric characteristics, counter movement jump, overhead medicine ball throwing and maximal dynamic strength were investigated in all the subjects. Results showed that there were significant differences in age, height and weight between starters and non-starters. There were no significant differences found between the two groups in strength and power values, except for squat performance, where starters were significantly stronger than non-starters.

Marques et al. (2009) investigated the anthropometric and strength characteristics of 35 professional male volleyball players. Players were categorized according to playing position and role: middle blockers (n = 9), opposite hitters (n = 6), outside hitters (n = 10), setters (n = 6) and liberos (n = 4). Height, body mass, muscular strength (4 repetition maximum bench press and 4 repetition maximum parallel squat tests), and muscular power (overhead medicine ball throw, countermovement jump) were assessed. Significant differences were found among the 5 positional categories. The results indicated that the middle blockers and opposite hitters were the tallest and heaviest players, whereas the libero players were the lightest. Differences were also found in bench press maximal strength, with the middle blockers and opposite player’s significantly stronger than the setters and liberos. The setter positional group had significantly poorer parallel squat performances than the outside hitter and opposite hitter groups. No other significant differences were found among groups for the strength and power parameters. These results demonstrate that significant anthropometric and strength differences exist among playing positions in elite male volleyball players.

Sotiropoulos et al. (2009) conducted a study to measure a number of anthropometric characteristics and vertical jump performance of elite youth women volleyball players, from the national teams of the Balkan countries, and make comparisons based on nationality and players positions. The sample consisted of eighty six athletes from Greece, Bulgaria, Serbia, Moldavia, Turkey and Romania. The volleyball players were also compared according to their playing position i.e. setters, outside hitters,
universals, middle blockers and liberos. The subjects were measured for body height, body mass, body mass index and body fat percentage and performed four types of vertical jump; a squat jump initiated from a knee flexion of 90°, a counter-movement jump, a counter-movement jump with arm swing and a drop jump from a dropping height of 40 cm from which reactive strength was also calculated. According to the results, the volleyball players of Greece and Romania had higher body fat percentage than Moldavia and Bulgaria’s players. Middle blockers were taller than the setters, outside hitters and liberos. Universals were taller than the setters and liberos, and the outside hitters than the liberos. No differences were observed in body mass index between the players and the teams, though middle blockers had higher body mass than the setters, outside hitters and liberos. In squat jump, counter movement jump and drop jump the volleyball players of Turkey had higher values than the volleyball players of Greece and Bulgaria. In counter-movement jump with arm swing, the volleyball players of Turkey had also higher values than the volleyball players of Greece, Bulgaria and Moldavia. Furthermore, the volleyball players of Turkey and Serbia had higher reactive strength values than the volleyball players of Greece and Bulgaria and the volleyball players of Turkey had also higher values than the volleyball players of Romania.

Sheppard et al. (2009) examined the strength, power, and anthropometric contributors to vertical jump performances that are considered specific to volleyball success. Anthropometric measurements, vertical jump ability, kinetic and kinematic data from an unloaded and loaded jump squat were assessed before and after 12 months of training in 20 elite male volleyball players. To examine the association between the change in each of the strength, power, and anthropometric variables with the changes in, a correlation analysis of the percent change of each variable with the percent change in countermovement vertical jump and spike jump was performed. A significant correlation was observed between changes in countermovement vertical jump and spike jump. Significant improvements in countermovement vertical jump were associated with increased peak force in the unloaded and loaded jump squat and greater relative power and peak velocity in the loaded jump squat. The significant increase in countermovement vertical jump was strongly associated with improved depth-jump ability. Significant increases in spike jump were related to increases in
relative power, peak force and peak velocity in the loaded jump and improved depth-jumping ability.

**Fonseca et al. (2010)** analyzed anthropometrical characteristics of Brazilian junior volleyball players. Sixteen male players were selected for 2006 South American Championship were evaluated, using Lohman protocols to access body fat, and Heath & Carter somatotype according to players position: setters, libero, middle, outside and opposite. Results indicated that the significant differences for body mass and height between middle and outside, and middle and opposite, were observed. However, no differences between player positions were observed for percentage of body fat and somatotype components. This result leads for athlete selection that looks for tall and linear players independent of player position. The only position that showed a difference was libero.

**Medeiros et al. (2010)** conducted a study on 16 male beach volleyball players from the Brazilian Circuit 2009. Jackson and Pollock's seven-skinfolds model was utilized. Results showed the greatest average value of skin fat was found for the abdominal skinfold (12.5 mm), followed by the suprailiac (11.4 mm) and thigh (10.8 mm). The minimum percentage body fat found was 4.6%, with the maximum being 16.0%, and the average 8.7%, below the mean theoretical ideal percentage of 15%.

**Maly (2010)** analyzed the body composition profile of elite women volleyball players in Europe Champions League 2008. Body composition was examined by means of multi-frequency bioelectrical impedance BIA 2000 M. The elite volleyball players showed a high proportion of lean body mass and low proportion of fat mass when compared to both common population and elite women volleyball players in available literature. Commonly used lean body mass and fat mass are accompanied by other parameters which may lead to individual assessment of eventual changes in player’s body composition caused by training periodicity (ratio between extra cellular mass and intra cellular mass, percentage of proportion of body cell mass, intracellular and extracellular fluid and others). The authors emphasize the importance of continual observation of changes in body composition in top level volleyball.

**Mridha (2010)** investigated male and female sub-junior volleyball players from six states of India. Body composition of the two groups were understood by height, weight, body mass index, percentage body fat, fat mass, lean body mass and waist-to-
hip ratio. Results indicated significant difference between the two groups in height, weight, percentage body fat, fat mass, lean body mass and waist-to-hip ratio. Male group was superior in height, weight, lean body mass and waist-to-hip ratio, and female group was superior in percentage body fat and fat mass than the other group. No difference was observed in body mass index of the two groups.

**Kumar and Sharma (2010)** conducted a study on selected anthropometric variables of female volleyball players of senior secondary school level. 24 female senior secondary school level volleyball players were evaluated. Selected anthropometric variables such as foot length, foot breadth, foot height, heel breadth, in step circumference, ankle height, ankle circumference, bowl of foot width, bowl of foot circumference, bowl circumference, buttock-knee distance, buttock-leg length, calf circumference, calf height, circumference of knee, knee height, knee height sitting, knee to knee width, leg length sitting, leg length without foot, length of lower leg and length of thigh were assessed. Results showed that there were significant differences in the variables of heel breadth, ankle height and bowl height. The significant difference were recorded when comparison of speed of movement between left and right foot was made.

**Gaurav et al. (2010)** conducted a study to compare the anthropometric characteristics and somatotype of the Guru Nanak Dev University, Amritsar’s male basketball players and volleyball players. Sixty three players (volleyball=36 and basketball=27) of age group 18-25 years were selected. All the participants were assessed for height, weight, breadths, girths and skin fold thickness. Results showed that basketball players had significantly higher height, weight and body surface area as compared to volleyball players. The basketball players were also found to have significantly greater biceps and supraillia skin fold thicknesses, calf circumference, percent body fat, total body fat, fat free mass and endomorphic component as compared to volleyball players. Volleyball players had significantly greater body density as compared to basketball players. The basketball and volleyball players of this study were found to have higher percentage body fat with lower body height and body weight than their international counterparts.

**Miyamoto et al. (2011)** analyzed 18 healthy male players from one team of the Japanese premiere volleyball league and the Japanese national team. The aim of this
study was to compare the fitness of Japanese premiere volleyball league team to Japanese national team and analyzed differences in athletes of high and low performance. 10 physical performance tests and body-composition was measured. The study was conducted in the regular training facility of Japanese premiere volleyball league team. Photo-detector and yardstick were used for measurements. Measurements for Japanese premiere volleyball league team were taken during the 2010 off-season, with Japanese national team taken during the same period 2009. The 10 performance tests are: 20 m dash, pro agility, T test, vertical jump, medicine-ball throw, standing triple jump, standing triple long jump, block jump, sit-up, and endurance test. Body-composition parameters are age, height, weight, body mass index, standing reach, vertical jump, and running vertical jump. Results showed that the significant difference was found only in the medicine-ball throw, while other tests did not reveal significant differences. Japanese national team had higher numbers in height, weight, and standing reach, recorded higher numbers in medicine-ball throw. Japanese premiere volleyball league produced higher numbers in vertical jump.

**Trajkovic et al. (2011)** carried a study to examine the positional differences in body composition and jumping performance of elite youth volleyball players. 28 youth national team players of Serbia were categorized as middle blockers, opposite hitters, outside hitters, setters, and liberos. The middle blockers and the opposite hitters are the tallest and the heaviest players in the team. The smallest values for body height and body weight were found among liberos. The results of percentage body fat have shown the smallest values among liberos and the greatest among the opposite hitters. The results in jumping performance tests indicated similar values for all the positions in the team with no statistically significant difference. Statistically significant difference was found among positions for body height, body weight and standing reach height.

**Zadraznik and Dervisevic (2011)** conducted a controlled laboratory study to explore the differences in the anthropometric measures in volleyball players among different levels of play. 301 volleyball players (115 males and 134 females) underwent the anthropometric testing at the faculty of sport in Ljubljana at the end of competitive season 2006–2007. Players were recruited from Slovenian 1st and 2nd league. Testing included body height, body mass and 9-site skin fold measurements. Later on body
mass index and body composition (percentage fat, lean body mass, somatotyping) was calculated. Multivariate analysis of variance with correction for age was used to evaluate the differences among different levels of play. Results showed that on multivariate level the differences among the 1st and 2nd division existed in both sexes. On univariate level the main differences in both sexes were related to the body height and lean body mass while in males the differences existed in the bone mass as well. Results suggest that body height remains the important factor of success in volleyball players.

Aouadi et al. (2012) conducted a study on thirty-three elite male volleyball players. The objective of the study was to examine the association between physical and anthropometric profiles and vertical jump performance in elite volleyball players. Anthropometric measurements (body mass, stature, body mass index, lower limb length and sitting height) together with jumping height anaerobic power of counter movement jump with arm swing were obtained from all subjects. Forward stepwise multiple linear regression analysis was performed. Results indicated that anaerobic power was significantly higher in the tallest players relative to their shorter counterparts. A significant relationship was observed between counter movement jump with arm swing and lower limb length and between the lower limb length and anaerobic power obtained with counter movement jump with arm swing. The study demonstrated that lower limb length was correlated with counter movement jump with arm swing in elite male volleyball players. The players with longer lower limbs had the better vertical jump performances and their anaerobic power was higher.

2.3 STUDIES RELATED TO RESPIRATORY FUNCTIONS

Pyorala et al. (1968) conducted a pulmonary function test on 57 former champion endurance runners or cross-country skiers and 53 non-athletes of the same age group. Results showed the former athletes differed from the control subjects by having a larger vital capacity and total lung capacity. Residual volume and functional residual capacity, as well as residual volume / total lung capacity × 100 and functional residual capacity / total lung capacity × 100, were slightly but significantly greater in athletes than in controls. Maximum voluntary ventilation tended to be greater in athletes than in control subjects. Maximum voluntary ventilation showed a significant negative correlation to age in healthy controls and athletes.
Onadekob (1976) studied lung function on sportsmen of Nigeria during the Western state sports festival. The sportsmen comprise 259 males and 151 females. They were made up of secondary school students, university undergraduates, young clerical and technical workers and soldiers. The forced vital capacity and forced expiratory volume in 1sec were performed using the wedge bellows vital graph. The results of the investigation are presented. It was observed that the mean forced vital capacity and forced expiratory volume in 1sec values were lower than the predicted mean values of normal Nigerians when matched for age, sex, height and weight. However, the mean observed forced vital capacity value of athletes was higher than the observed forced vital capacity value of non-athletes.

Barlett and Mance (1984) conducted a study to determine expiratory reserve volume, vital capacity, in lean female athletes within members of two collegiate women's teams: gymnastics and track. The runners provided a control group by being similar to gymnasts in age, weight, expiratory reserve volume, expressed as a percent of vital capacity, (expiratory reserve volume X vital capacity -1) 100, was significantly less in the gymnasts as compared to the runners.

Lakhera et al. (1984) carried a study to evaluate pulmonary functions in Indian athletes and sportsmen associated with different athletic events and games. It was found that swimmers were having significantly higher vital capacity and forced expiratory volume values than all other athletic groups.

Ghosh et al. (1985) conducted a study of pulmonary capacities of different groups of sportsmen in India. Pulmonary functional capacities, vital capacity, maximum voluntary ventilation, forced expiratory volume in 1second and forced expiratory volume 1.0 (per cent VC) of 168 sportsmen belonging to different sports activities and of 10 controls have been studied. It was observed that all these pulmonary functional capacities of different groups of sportsmen were higher than those of the control group. The mean vital capacity of the basketball, boxing, cricket, football, hockey and the table tennis groups, the mean maximum voluntary ventilation of all the groups except the athletic, badminton and football groups, and the mean forced expiratory volume in 1second of football, hockey, swimming and volleyball groups were significantly higher than those of the control group.
Hagberg et al. (1988) conducted a study on pulmonary function in young and older athletes and untrained men. They have compared the lung volumes and pulmonary functions of older endurance-trained athletes with those of healthy sedentary age-matched controls, young athletes, and young untrained men the average values for maximal voluntary ventilation and residual volume were also larger in the older athletes. It was found out there was significant increase in vital capacity, total lungs capacity, and forced expiratory volume in older athletes in comparison with older sedentary group when normalized for age and height.

Morrow et al. (1989) worked on the validity of commonly recommended pulmonary function prediction equations of two samples (n1 = 156 and n2 = 218) of well-trained athletes. Pulmonary function measures were typically very reliable but inaccurately predicted with recommended equations based upon anthropometric characteristics. Results found the newly created pulmonary function prediction equations are more valid for well-trained athletes than the equations in use for the general population.

Cordain et al. (1990) conducted a study to determine whether respiratory muscle strength is related to pulmonary volume differences in athletes and non-athletes. 11 inter-collegiate female swimmers, 11 female cross-country runners and two non-athletic control groups were evaluated. Pulmonary parameters including maximal inspiratory pressure, maximal expiratory pressure, vital capacity, residual volume, inspiratory capacity and functional residual capacity were measured. Result indicated that swimmers exhibited higher volumes and capacities. It was determined that swimmers had greater respiratory muscle strength related to the pulmonary volume difference in athletes than non-athletes.

Lakhera et al. (1994) evaluated lung functions of 14 boys and 11 girls practicing for middle distance running events. Results revealed that there was significant improvement in pulmonary function in adolescents. Physical exercises during growth may help in developing a reduced resistance to expiration and a greater endurance in respiratory muscles.

Doherty (1997) conducted a study on Greek swimmers, land based athletes, and sedentary controls. Four hundred and fifty nine asymptomatic Greek children and young adults, including 159 swimmers, 130 land based athletes and 170 sedentary controls were evaluated. Pulmonary parameters such as forced vital capacity, forced
expiratory volume in one second and peak expiratory flow were measured. The results indicated that the male and female swimming groups had larger forced expiratory volume in the first second than both land based athletes and sedentary controls.

**Lakhera and Kain (1997)** conducted lung function tests on females. Vital capacity, forced vital capacity, forced expiratory volume in 1 sec, expiratory reserve volume and inspiratory capacity were recorded using conventional closed circuit spirometry. Maximum voluntary ventilation was estimated by collecting expired air during deep and rapid breathing in a 100 liters metrological balloon for a period of 15 seconds and measured its volume. It was observed that Ladakhi females were having significantly higher vital capacity, forced vital capacity, maximum voluntary ventilation and forced expiratory volume in 1 second values than their counterparts.

**Mehrotra et al. (1998)** carried a study on sportsmen engaged in various sports i.e. football, hockey, volleyball, swimming, basketball and compared with each other and with the controls. Pulmonary parameters such as forced vital capacity, forced expiratory volume and peak expiratory flow rate measured. The results indicated that all the sportspersons had higher values of lung functions than the controls.

**Adegoke and Arogundade (2002)** investigated relationship between chronic exercise and lung function as well as basal oxygen consumption rate in a Nigerian setting. This was done by determining some lung volumes and capacities i.e. tidal volume, forced vital capacity, forced expiratory volume in the first second and basal metabolic rate in athletes and non-athletes. Results indicated that tidal volume and forced vital capacity significantly higher in male athletes than male non-athletes. These results suggest that the respiratory functional capacity of athletes in Nigeria could be generally superior to that of non-athletes.

**Verma et al. (2002)** conducted a study to know the changes in lung function in man in different age groups using univariate statistical techniques. Attempt has been made in the investigation to study simultaneous changes in some lung function tests (viz. vital capacity, forced vital capacity, forced expiratory volume for one second, expiratory reserve volume, inspiratory capacity and maximum voluntary ventilation) at different age groups in healthy Indian males. It was concluded that remarkable significant changes take place in lung function after the age of forty years.
Boskabady et al. (2004) worked on 336 healthy, non-smoking subjects including 187 males (height 103-188.5 cm) and 149 females (height 104-183 cm) aged 8-18 years of urban young population in the city of Mashhad (north-east Iran). Spirometric flow and volume such as forced vital capacity, forced expiratory volume for one second, maximal mid-expiratory flow, peak expiratory flow, maximal expiratory flow at 75, 50 and 25% of the forced vital capacity, tidal volume, inspiratory reserve volume, expiratory reserve volume, inspiratory capacity, and vital capacity were measured. Results indicated that there were positive correlations for each pulmonary function variable with height and age.

Josi et al. (2008) conducted a study to assess the correlation of pulmonary functions with body fat percentage in young individuals. A total of 132 young students (68 males and 64 females of 18 to 21 years of age) were tested. Pulmonary function tests (static and dynamic) were recorded. The percentage of body fat was estimated by measuring skin fold thickness at four sites. It was observed that in female’s body fat % had negative correlation with expiratory reserve volume, forced vital capacity, and maximum voluntary ventilation. These results indicated that increase in percentage of body fat and central pattern of fat distribution may affect the pulmonary function tests.

Chatterjee et al. (2010) evaluated vital capacity of healthy Nepalese young females and compare their values with healthy Indian counterparts. 42 Indians and 54 Nepalese young non-smokers, female students of 18 to 20 years of age were recruited for this study. Results showed the mean vital capacity of Nepalese and Indian girls were 2650.31 ± 464.34 and 2629.21 ± 449.97 ml respectively. No significant difference was found in the mean vital capacity of Nepalese and Indian female students.

Thaman et al. (2010) examined the effect of physical training on pulmonary function tests in border security force trainees of India. Pulmonary function tests of Border Security Force trainees were compared with controls. Pulmonary function tests of 100 healthy Border Security Force trainees before and after their rigorous physical training of 9 months duration was evaluated. The values obtained from tests compared with 100 healthy medical students who were chosen as controls. The Pulmonary function tests were carried out with a computerized spirometer “Med-Spiror”. It was
observed that higher lung volumes and flow rates were achieved in Border Security Force trainees after their training period, as compared to their own values obtained before their training period and to those of controls.

**Ignjatovic et al. (2011)** investigated the influence of additional resistance training on cardiorespiratory endurance in young male basketball players. Experimental group subjects trained twice per week for 12 weeks using a variety of general free-weight and machine exercises designed for strength acquisition, beside ongoing regular basketball training program. Control group subject participated only in basketball training program. Oxygen uptake and related gas exchange measures were determined continuously during maximal exercise test using an automated cardiopulmonary exercise system. Results from the experimental group showed no change in cardiorespiratory endurance, while muscle strength and power of main muscle groups increased significantly. These data demonstrated no negative cardiorespiratory performance effects on adding resistance training to ongoing regular training program in young athletes.

**Plavsic et al. (2011)** conducted a study to know the differences in respiratory parameters between the two groups of elite national water polo and volleyball teams. 32 male professional players (15 water polo and 17 volleyball) were evaluated. The research was conducted in the laboratory for functional diagnostic in the National Institute of Sport in Belgrade. Measurement of respiratory parameters was performed using a cosmed spyrometer Pony graphic. Results indicated that there was no statistically significance difference in respiratory parameters between elite national water polo and volleyball teams. There were no significant differences in static and dynamic respiratory parameters among the water polo and volleyball players.