CHAPTER-II

REVIEW OF RELATED LITERATURE

The success of work is built on the foundation of the required knowledge of a particular field. The pre-existing knowledge helps the learner to know what is already known and what is yet to be known. In the field of research, this knowledge can be acquired from the various research reports, journals, abstracts, dissertations, thesis, books, magazines etc.

According to Ary (1972) "The knowledge of the related literature brings the researcher up to date on the work which others have done and thus to state the objectives clearly and concisely. It also provides the understanding of the research methodology which refers to the way the study is to be conducted."

Almost all human knowledge is preserved in books and libraries. Unlike other species that must start a new life with each generations, it is an advantageous to human being that they make use the accumulated and recorded knowledge of past (Best, 1977).

In this study, the structural aspects of the body such as kinanthropometric characteristics, somatotyping and body composition only has been studied. Many researchers have analyzed these structural aspects of the body in relation to different games, geographical and climatic condition, gender, nutrition, age, socio-economic status, performance level etc, and had given different theories. In order to study these structural aspects thoroughly the literature has been divided into two parts. In the first part various games and sports have been studied and in the second part the jumping and throwing events have been covered.

2.1 STUDIES RELATED TO VARIOUS GAMES AND SPORTS

Riendean et al. (1958) carried out a study to find out the relationship between percentage of fat and performance in selected motor fitness tests. There was significant negative correlations from -0.29 to 0.63 between percent body fat and selected motor fitness tests. The study revealed that the test items most affected by fat were those which involved running and jumping.
Tanner (1964) analyzed the physique of athletes of Olympics and concluded that the sprinters were short and muscular men as compared to middle distance runners. Their shortness was mainly due to short trunks not due to short legs. The 110m hurdlers were large, long legged sprinters. They were as muscular as the 100m sprinters but they had long legs than sprinters. The leg length proportionally was same as those of 400m runners. The 400m runners were large legged, broad shouldered in relation to their hips, and fairly heavy muscled whereas long distance runners were small, short legged, narrow shouldered and inferior in musculature. The 5km walkers were found to be similar to 1500 runners. It was observed that 110m hurdlers and sprinters had same average somatotype. He observed that as the running distance of 100m, 400m, 800m and long distance running events was increased, the mesomorphy of these athletes decreased and ectomorphy increased. The average somatotype of steeplechasers and walkers were no far off from middle and long distance runners averages.

Carter (1970) studied 34 Olympic runners and found that all runners were uniformly low in endomorphy. The 800m runners and 1500m runners were half a unit higher on mesomorphy than the 5000m and 10000m runners were half a unit higher in ectomorphy than the other groups.

Costill et al. (1970) carried out a study on 114 marathon runners during 1968 United State Olympic Marathon runners. The data showed that the average age of the marathon runners was 26.1 year, average height was 175.7 cm, body weight was 64.2kg and body fat percentage was 7.5%.

Eiben (1972) examined 125 women athletes who were participating in European Athletic Championship. It was noticed that the women sprinter athletes had small dimensions in each anthropological character as compared to other women athletes. Their legs were longer as compared to their trunk. Their heights were found shorter due to small trunk. The results indicated that sprinters had less muscular upper extremities but the lower extremities mainly the lower legs were found to be much muscular and stronger. Hurdler runners had same stature as sprinters. They also had longer legs with shorter thighs but their trunks were a little longer than the sprinters, whereas middle distance runners had longer and narrower trunks.
Novak et al. (1972) worked on 28 track runners and marathon runners. There skin folds were taken and it was observed that 400 m runners and 800 m runners had significantly higher skin folds at triceps and subscapular sites than the marathon runners. When the sum of triceps, subscapular, iliac crest, umbilical, thigh and calf were calculated from the mean, the values declined from 1500-3000 m runners (33.7 mm) to 400 m to 800 m runners (33.5 mm) to 5000-10000 m runners (28.7 mm) and to marathoners (22.6 mm).

De Garay et al. (1974) investigated the Olympic athletes who participated in Mexico. The study showed that the sum of three skin folds values of all track group was low, but the sprinters were with greater skinfolds than other track athletes. Some of the leanest athletes among them were track athletes, but most were in the long distance runners. The lowest skinfold recording was 11.2 mm for a distance runners but one sprinter was the lowest with 11.7 mm. The sprinters were significantly higher in endomorphy and mesomorphy than all other groups except walkers and were significantly lower in ectomorphy than all other groups.

Stepnicka (1977) carried out a study to know the relationship between the somatotype, body posture and physical performance in sports. The study showed that in high performer athletes, a certain somatotype is a morphological pre-supposition for their high sports performance. It was noticed that the weight lifters had a high value of mesomorphy. They also had short limbs which help them in lifting the weight.

Watson (1977) took weight, height, skinfold thickness and mid arm circumference of 540 males and 117 females aged 20-24 years old, who took part in the 1st African University games held in at the University of Ghana, legon. Body fat contents, Quetelet’s index (weight/ height x 100) and mid arm circumference were derived from the measurement taken. The physique of the subjects as assessed by Quetelet’s index showed that both male and female subjects from the various countries were of medium bodybuild. The body fat content for males was between 10% or 12% with the exception of the Egyptians (12.8%) while that of females was between 23-24%. Body measurements of the subjects remarkably similar with that of international standards with the exception of the triceps skinfold thickness which was only approximately 60% of the standard values. The low values of triceps skinfold
thickness were probably due to differences in the distribution of subcutaneous fat at different sites in the body as found between Caucasian and non Caucasian population groups.

Amusa (1979) carried out a study to know the relationship between the playing ability and selected body measurements. The total number of 46 well conditioned soccer players having atleast two years playing experience at the college levels were studied. Weight and height were considered as the most important factors in soccer performance.

Ward et al. (1979) conducted a study on seven first class Olympic weight lifters to know the relationship between anthropometric measurements and performance. It was found that there is strong relationship between body weight and amount of weight lifted by the lifters.

Vaccaro et al. (1979) studied 15 women basketball players of University of Maryland to determine the physiological profiles of elite women basketball players. Body composition, somatotype were assessed and the results indicated that measures of height and weight were greater than that of average female and most of other women athletes. Percentage of fat was less than female athletes, but greater than those reported for women runners of district level and mean of somatotype was similar to normal group.

Bhatnagar (1980) worked on athletes, kabaddi players and volleyball players of Madhya Pardesh of rural area. He studied their height, weight and skinfolds. The rural sportsmen of M.P. were lighter and shorter with less amount of fat as compared to normal urban Punjabi, where as the morphological difference is concerned among the U.P. players, the volleyball players were shorter and lighter with minimum amount of fat as compared to athletes and kabaddi players.

Kansal (1980) carried out a study on physique and body composition of Zonal Champion of Interuniversity football players. The study revealed that the defenders were significantly heavier and taller than forwards. Thus, the forwards had less percentage of body fat and more lean body mass as compared to defense players. Further, he stated that the defenders had much developed calf and thigh muscles as compared to offenders. The defenders had also broader femur bicondylar.
Meszaros and Szmodis (1980) examined athletes and non-athletes (young and adults). The non-athletes were university students and the young subjects were school children. All athlete subjects were engaged in track and field events. It was observed that adult male track athletes were taller, heavier and had a broader chest and larger hands than the rest of the reference group. However, no significant difference was found between the two groups in biacromial breadth and lower arm circumference, although one would have expected it by stature. Twelve years old male athlete had taller stature and broader shoulders, but narrower chest and slimmer than the reference group.

Carter (1982) observed the somatotype of male and female of Montreal Olympics. When they compared both sexes the males were found to be less endomorphic, more mesomorphic and less ectomorphic than the females. The mean of somatotype for male athletes were 2.1-5.2-2.6 and female athletes were 2.8-3.8-3.1.

Puhl et al. (1982) noted the absolute relative physical and physiological characteristics of elite men and women volleyball players. The total no. of 8 male and 14 female subjects were investigated and results showed that the men were taller, heavier and had a higher body density, lean body weight and low fat. The differences in the muscle mass between the two groups were apparently due to sex differences.

Fleck (1983) worked on 528 male athletes participating in 26 Olympic events and 298 Female athletes participating in 15 Olympic events underwent determination of body fat percentage (%fat) and lean body mass (LBM) via Hydrostatic Weighing and Anthropometric Methods. Result showed that, in general, athletes involved in a sports where their body weight is supported, such as Canoe and Kayak (males 13.0 ± 2.5% females 22.2±4.6%) and swimming (males' 12.4±3.7% females 19.5±2.8%) tended to have higher % fat values. Athletes involved in sports, where the weight class has to be made to compete, such as boxing (males 6.9 ± 1.6%) and wrestling (male junior world freestyle 7.9± 2.7%) events such as the 100m, 200m and 400m in athletes (male 100& 200m 6.5± 1.2% female 100m, 200m and 400m, 13.7±3.6%) that were very anaerobic in nature and extremely aerobic events such as the marathon (males 6.4±1.3%) demonstrated lower % fat values. Athletes involved in sports where body size is a definite advantage, such as basketball male 84.1±6.2 kg female (55.3±4.9 kg) and volleyball (males 75.0±6.6kg, females 58.4±4.5kg) tended to have a largest LMB.
**Sodhi (1983)** reported that Indian wrestlers were over weight by 3.6 kg in their respective weight category due to higher fat in their body as compared to Olympic champion of corresponding weight categories.

**Orvanova et al. (1984)** studied somatotype of weightlifters according to the weight categories. The 52 Kg class had higher ectomorphy and lower endomorphy. The three upper weight classes showed extreme endomorphy whereas middle weight classes showed better mesomorphy than other somatotyping components. The data showed that mesomorphy had the highest rating through out the series with the increase in weight and ectomorphy decreased as endomorphy and mesomorphy increased.

**Bhatnagar and Singal (1986)** analyzed 12 athletes and 19 volleyball players from rural area of Assam and Madhya Pradesh. They examined 23 anthropometric variables and noticed that the volleyball players and athletes of Assam were heavier and taller than the volleyball players and athletes of Madhya Pradesh. Athletes of Madhya Pradesh had greater circumference and skinfolds of upper body whereas the athletes of Assam had greater circumferences and skinfolds of lower body. The volleyball players of Madhya Pradesh possessed greater circumference and diameter of upper body but the volleyball players of Assam had greater circumference and diameter values of lower body. The skinfolds of Assam volleyball players were also found greater. The diameters of Madhya Pradesh athletes were found greater but the Assam’s athletes had broader humerus and bicristal diameters.

**Borms et al. (1986)** conducted a study on world’s best male body builders of 19 countries belonging to different racial backgrounds. They noted 35 anthropometric measurements of these body builders and it was concluded that the body builders of different weight class had different height and weight whereas their somatotypes were nearly same and the mesomorphic component of each category was also same. The main objective of each body builder is to make their muscles big and sharp, that is why the body builders in different categories achieved similar hypertrophy.

**Brockhoff et al. (1986)** carried out a study to know the morphological differences between young gymnasts and non athletes matched for age and gender. They investigated 18 female and 17 male gymnasts and equal number of girls and boys who were non sports person, means they were not participating in competitive sports. The study showed that the gymnast were shorter than the control group. The female
gymnasts had lesser percentage fat. Mesomorphic component was found greater in
gymnasts whereas endomorphic component was higher in the controls.

**Grimston and Hay (1986)** conducted a study to know the relationship among
anthropometric measurements and stroking characteristics of college swimmers. It
was found that although swimming speed is little influenced by physique of
swimmers, the combination of stroke length and stroke frequency used to attain a
given speed is very much a function of physique.

**Slaughter (1986)** carried out a study to present an objective method for estimating
musculo-skeletal size in relation to height for use in the study of body physique of
athletes and non-athletes children and youth. The study showed that athletes of
different events were found to differ in fat free body aspect of physique. It was also
noticed that ice hockey players having the greater fat free body in relation to height
and middle distance runners had lesser fat free body in relation to height.

**Stepnicka (1986)** noted the relationship between somatotype and motor performance
of Czechoslovakian athletes. It was observed that with the change of training and
techniques in respective sports the somatotype of top sports persons now-a-days vary
from those the sportspersons of the past. The study showed that endomorphic and
ectomorphic components contributed least in physical performance and appears to
have a poor body posture.

**Singh and Debnath (1988)** worked on Indian national women gymnastic team to
study physique and somatotype characteristics. Further, the Indian team was
compared with the Olympic gymnasts who had participated in Mexico Olympic 1968
and Munich Olympic 1972. The female Olympic gymnasts of 1968 Olympics had
significantly greater mesomorphic component and female Indian gymnasts had
significantly greater calf skinfold than each other. The 1972 Olympic gymnasts were
found longer in stature having lesser subscapular, suprailiac and calf skinfolds as
compared to Indian women gymnasts. In case of Indian gymnasts as compared to
those of China, Japan and Korea in X Asian games 1986, it was also observed that the
Chinese gymnasts were significantly lighter and shorter in stature than their Indian
counterparts. Further, Indian gymnasts were older than the Korean team. The study
revealsthat higher amount of fat and heavier body weight were responsible for the
poor performance of Indian gymnasts.
Singh et al. (1988) studied on 100 jat Sikh men of different regions of Punjab state who were healthy and between 17-25 years of age. They noted their height, weight, limb circumference, skeletal diameters and skinfolds. The data showed that the Jat Sikh males were comparable in height, weight with contemporary pooled Punjabi, but they were much taller as compared to men of Himachal Pradesh and all pooled Indians.

Sidhu et al. (1989) worked on the physique of national level police players of hockey, football, basketball and volleyball. The study revealed that the hockey players were significantly less endomorphic than football and volleyball players, whereas hockey and football players showed the highest mesomorphic component and football players were the least ectomorphic component than all the other groups.

Sidhu et al. (1989) studied the somatotypes of fifty state level women players of hockey, basketball, volleyball and athletes from the age group of 18 years to 22 years. It was concluded that the average body type of women hockey team was leptomorph-metroplastic, women basketball player were leptomorph-hypoplastic and the athletes were leptomorph-metroplastic.

Uppal et al. (1989) conducted a study to compare and find relationship of percentage of body fat, body weight of physical education students belonging to different weight categories and concluded that the subjects belonged to heavier weight category had significantly high percentage of body fat as compared to the middle and lowest weight categories.

Bharadwaj et al. (1990) measured body density, extremity segments and total body volume together with 15 anthropometric variables of 93 Indian sportsmen and athletes. The Group consisted of runners, boxers, basketballers, footballers, gymnasts, wrestlers, swimmers and a control group of active soldiers not participating in such athletic or sports events. The wrestlers with the larger body volume were the fattest. The gymnasts were smallest, leanest and had greatest lean body mass per kg body weight. Extremity segments volumes when expressed as the percentage of the total body volume or as percentage of adjacent segments further differentiated the groups. On the basis of arm and leg segment, volume, proportions alone it was possible to distinguish many groups from each other. Thus, gymnasts, basketballers and wrestlers could be clearly separated on these criteria. The original development characteristics
in different classes of sportsmen and athletes appeared to be sound in ergonomic consideration.

Sharma and Shukla (1990) carried out a study on hockey and football players of Punjab in National Championship. It was noticed that the football players had significantly greater chest circumference, biacromial, humerus and femur bicondylar breadth and thigh and calf muscles were bigger as compared to hockey players.

Sharma et al. (1990) examined hockey players according to their field position. The significant differences were found in the physique of players as fullbacks were significantly heavier and taller, their upper extremities were longer, the shoulder, chest and hips were broader and the skinfolds and circumferences were also greater, whereas half backs were found to be smaller and lighter. In forwards they found greater lower extremities and smaller bi-iliocristal breadth. The study revealed that weight and stature of players increased according to their field position.

Sidhu et al. (1990) observed 105 university athletes and noted that the sprinters were average in age 20.68 years old, in height they were 170.65 cm tall and in weight they were 57.44 kg heavy. Middle distance runners were 19.78 yr.old, 169.51 cm long and 57.34 kg heavy, whereas long distance runners were 20.99 yr, 169.63 cm long and 56.26 kg in respect of age, height and weight. The somatotype rating of short distance runners was 1.61-3.62-3.65, middle distance runners had 1.52-3.68-3.56 and long distance runners had 1.5-3.5-3.91.

Snell and Vaughan (1990) of Texas University conducted longitudinal physiological testing on group of elite American female long distance runners. It was observed that each of them has an optimum weight and composition for peak performance. The body composition figures can be used along with race performance as an aid for future reference. None of these performances ran the best personal record with body fat greater than 11%. In maximum cases, peak performance was found with body weight between 6 to 8 percent.

Sodhi et al. (1990) measured height, sitting height, and hand span of 287 volleyball players and 196 non players, whose age was between 14 to 16 years. It was noticed that these variables gradually increased with the age. In volleyball players hand size
also increases with age. They also noted that taller height with longer legs and arms and greater hand span were helpful in volleyball games.

**Bale (1991)** conducted a study to determine the physique and body composition of young female basketball players and to examine these variables in relation to their playing position. Eighteen members of the under seventeen England basketball teams were measured on twenty different anthropometric sites from which somatotype and body composition were calculated. The variables of basketball players grouped according to the playing position were then compared statistically using ANOVA. The results showed that the centers had the largest measures of physique and body composition followed by the forwards and then the guards. These differences were significantly particular between the centers and the guards. The centers were much taller, had longer limb length, hip width and were more muscular.

**Debnath and Bawa (1991)** analyzed 41 gymnasts in National Junior Gymnastic Championship. They noted age, weight, height, diameter of biacromial, humerus, femur bicondylar and circumference of upper arm, fore arm thigh and calf. Skinfold measurements of biceps, triceps, subscapular, suprailiac and calf muscles were also taken. The results indicated that the mediocre level junior performer in gymnastics had significantly heavier weight, larger thigh and calf circumference, lower lean body mass and mesomorphy components than high level performer group.

**De et al. (1991)** worked on South Asian athletes and reported that the long distance runners were mostly thin built (predominately ectomorphic). The short distance runners were predominantly mesomorphic as reflected by their muscular body and had more weight.

**Igbokwe (1991)** observed 23 boxers, 18 weightlifters, 21 wrestlers and 19 people as a control group. The study showed that among their groups the controls (4.02) were the most significantly endomorphic (P<00.5). The weightlifters (5.12) and the wrestlers (5.04) were more significantly mesomorphic (<0.05) than the boxers (3.18) and the control group (3.06). The wrestlers and weightlifters dominated in mesomorphy. Strength related skills were better performed by those with mesomorphic physique.

**Scott (1991)** carried out a study on national level hockey players of South Africa. The results revealed a mean mass of 75.3 kg with a range from 57 kg to 100.6 kg. These
masses were significantly greater than those of the Indian players of Kansal et al. (1983) whose average was 60.8 kg but comparable with the South Australian in the study by Withers et al. (1977) whose average was 73.2 kg. In percentage body fat it was clear that subjects with a mean of 11.1% did not carry much excess body fat. This result was marginally above that of 8.73-9.58% reported by Sidhu et al. (1979) and well below that of 16.7% presented by Withers et al. (1977). Further, he stated that it is interesting to note that when the mean body fat percentage of the 12 participating team was plotted against the team positioning at the end of the tournament, there was a concomitant rise in the amount of body fat in accordance with the descending order in tournament position. Regarding the body leanness of the hockey population of this project the Reciprocal Ponderal Index (RPI) was calculated (height/√weight). There was minimal variation of this parameter and the average of 41.77 (SD = 0.33) was clear evidence of linearity of the players. The subject’s somatotypes were determined using the Heath Carter anthropometric method and the overall somatotype for South Africa male hockey players was calculated to be 2.2-5.3-2.3 indicating a predominance of muscularity. Further, study showed that the male subjects appeared to be ecto-mesomorphic in comparison with the female endo- mesomorphic characteristics.

Sodhi et al. (1991) studied different players from different disciplines including athletics, badminton, basketball, boxing, cycling, diving, gymnastics, football, hockey, swimming, volleyball, wrestling, weight lifting and waterpolo. Study showed that the mean value of bone weight of volleyballers was 12.69 kg ± 1.45 kg, muscle mass was 31.59 kg ± 4.44 kg, fat percentage was 12.63% ± 2.34%. Whereas the bone weight is concerned the volleyballers were close to throwers of hammer, discus and decathletes but heavy weight wrestlers had greater bone weight than volleyballers. In muscle mass the throwers of discus, hammer, and shot, decathletes, weightlifters and middle heavy weight wrestlers had better status than volleyballers who were better than other athletes and players. In the fat percentage volleyballers were less fatty than waterpoloists, divers, and goalkeepers in football, fullbacks and forwards in hockey, throwers, decathletes, pole vaulters and wrestlers. In fat content estimation volleyballers were almost close to badminton players, cyclists, stoppers, backs, halves in football, halves in hockey and light class wrestlers. Further, when Indian players were compared with their counterparts, the Indian players were poorer in the
development of mesomorphic component of somatotype. Further greater pre-

dominance of ectomorphic component was still persistent in Indian sportsmen. The
Indian players were found shorter in height and lighter in weight in comparison with
the players of other countries who participated in Olympic Games. All components
were assessed by using Matiegka’s Method.

**Bale et al. (1992)** worked on 103 boys and 65 girls from 13 to 18 years old to know
the cross sectional nature of the effect of age, height and body mass in motor
performance during adolescence. The results showed that boys were significantly
more mesomorphic than girls while girls were significantly more endomorphic than
boys. Higher percentage of fat and more endomorphy were significantly related to
poor performance for relative aerobic capacity 40 yard dash, and agility in boys.
Mesomorphy had higher relationship with performance variable among boys than
girls.

**Harinder et al. (1992)** carried out a study on 150 sports boys and 182 as a control
group ranging from 13 to 18 years to determine the somatotype. The skinfolds of
triceps, subscapular, suprailiac and calf, the circumference of upper arm, calf, humerus bicondylar diameter and femur bicondylar diameter were noted for each
subject apart from height and weight. It was concluded that with age endomorphic and
mesomorphic component is increased and ectomorphic component is decreased in
sports boys, whereas in control group endomorphic component is increased and
mesomorphy and ectomorphy is decreased with age.

**Sodhi and Rajni (1992)** studied 26 national level boxers having average age 22.7 to
25.7 years divided in three broad categories viz. light, medium and heavy class of
body weight. The light class consisted of boxers from pin, fly, bentam and feather
weight, the middle class from light welter and middle weight and the heavy class from
light heavy, super heavy weight categories. The boxers of their study had been
examined for 33 anthropometric measurements. The boxer of light, medium and
heavy categories had shown a gradient of increasing body measurements i.e. light
class being the lightest and shortest, the heavy class being almost the heaviest and the
tallest, while the middle weight class had come in between the both in almost all the
anthropometric measurements. F-ratio values were found to be highly significant in
case of each measurement. In age however, the F-ratio turned out to be an
in insignificant factor between different categories of boxers. The post-hoc differences between the means of light, medium and heavy class categories of boxers in most of the anthropometric measurements had also shown significant differences. Further, when their pooled samples were compared with the boxers of Olympics level, the Indian boxers were found to be taller and heavier as well as older in age as compared to the Olympic level boxers. The difference in height and body weight could be partly due to heterogeneous nature of samples. Further, in somatotype the Indian boxers were found to possess significantly more body fat with less development mesomorphic components, but in ectomorphy the two did not differ from each other.

Singh and Sangral (1994) conducted a study on male handball players at different levels of performance. For this anthropometric study the twenty four subjects were selected who had played at state and national level. The players were categorized into two groups on the basis of their performance as high performer and low performer. It was found that high performer had significantly larger values for weight, sitting height, arm span, thigh circumference and bone mass as compared to low performer.

Talwar et al. (1994) worked on adolescent girls of Punjab to know socio-economic difference in somatotype. The study revealed that the Punjabi girls belonging to upper socio-economic status are appreciably superior in body size than who belonged to the lower socio-economic status. The data showed that significantly higher study of endomorphy associated with lower rating of mesomorphy as compared to lower socio-economic status girls.

Sandhu and Sodhi (1995) measured the weight and stature of 30 Indian national volleyball players and concluded that the Indian players were shorter in height and lighter in weight as compared to players of other ranking countries.

Singh et al. (1995) studied anthropometric characteristics of 55 Indian male cyclists. The study revealed that these cyclists were smaller, lighter and had leaner skinfolds, when they were compared with Indian camper cyclists.

Sodhi et al. (1995) studied to know the physical structure of tribals of Chhotta Nagpur and North Indian male hockey players whose age was between 14 to 16 years. It was concluded that the North Indian players had greater body weight, skinfolds,
circumference as compared to tribals of Chhota Nagpur, but the humerus and femur bicondylar diameter of tribals were found greater as compared to other players.

Godinho et al. (1996) studied 36 male and female Dutch Korfball players. The purpose of this study was to find whether korfball players possess typical characteristics of physique and body composition and to relate these characteristics to the players of other sports. It was found that korfball players were smaller and lighter than basketballers and volleyballers but heavier and taller than other team sports players. Korfball players have less relative body fat, more lean body mass, more limb fat, and less trunk fat than the other athletes. Male korfball players presented a somatotype (1.9-4.4-3.4) similar to endurance athletes and an endomorphic value lower than the other athletes. The only apparent similarity between female korfball somatotype (3.2-4.0-2.8) and other athletes somatotypes is the dominance of mesomorphy. The average height of male and female korfball was 186.55cm and 173.38cm and weight 77.78kg and 66.47kg respectively.

Sidhu et al. (1996) conducted a cross sectional study on 444 boys who were sports persons and 401 boys who were non-sports persons of Punjab. They all were in the age from 11-19 years. Anthropometric variables as height, weight, skeletal diameter, circumference and skinfold thickness were measured using standard techniques. It was concluded that the sports boys were taller, heavier, greater trunk, wider shoulders and hips, slightly thinner fatfolds at triceps and sub-scapular sites than the control group of non-sports boys. Further, the sports boys when compared with Olympians of same age group were found shorter in body frame as well as in all the other body measurements.

Sodhi and Rajni (1996) analyzed the anthropometric measurements of elite Indian waterpoloists. They studied 28 anthropometric variables of 22 top level waterpoloists, whose average age was 22.7 years. When they compared Indian waterpoloists with the Olympians of same age, they found that the Indians waterpoloists were significantly different in anthropometric variables. The weight and height of the waterpoloists were less. The study showed that the Indian waterpoloists had significantly smaller shoulder breadth and hip breadth than Olympian players. In body composition, the present waterpoloists were found significantly heavier in bone mass, fat mass, and muscle mass than the controls.
**Wan Nudri et al. (1996)** conducted a study to determine the anthropometric measurements and body composition of selected national athletes. The total of 84 male athletes from 10 different types of sports, 24 female athletes from 5 types of sports were studied. The height and body weight of subjects were measured using the sega weighing balance with height attachment. Skinfold thickness measurements were taken at 4 sites biceps, triceps, sub scapular, suprailiac. Percentage of body fat was calculated from the sum of 4 measurements of skinfold thickness. Based on body mass index (BMI) most of the male (68 subject's means 81%) and female (19 subject's means 79%) athletes were classified as normal. The percentage average body fat for both male and female athletes were 13.8 ± 4.5% and 24.7 ± 5.3% respectively. The male and female athletes also had lower percentage of body fat when compared to non athletes. However, these athletes had slightly higher percentage of body fat when compared to those in selected countries.

**Bawa and Debnath (1997)** studied the junior Indian male gymnasts to know the morphological characteristics and physical abilities in relation to their performance. Subjects were divided into 4 groups as international performance group, high performance group, mediocre performance group and low performance group. The result showed that Indian International and high performance group possessed significantly greater upper arms, forearms, thigh and calf circumference than the mediocre and low performance groups.

**Dey et al. (1997)** carried out a study to find anthropometric measurements of seven hundred school going healthy girls of Eastern region and North Eastern region of India. These girls were between 8-14 years of age. It was concluded that Eastern region girls were taller than the North Eastern region girls and North Eastern girls were heavier than Eastern regions girls.

**Reeves et al. (1999)** conducted a comparative study to know the anthropometric measurements and body composition of football teams in the United Kingdom and Malaysia. The total thirty two subjects were studied from the team of St. Mary’s University of UK and the Selangor Reserved Team of Malaysia. The height, weight, skinfold thickness of biceps, triceps, subscapular and suprailiac were measured. They concluded that the U.K. team were significantly heavier, (P<0.05) taller (P<0.05) and had a higher body fat content (P<0.05) than the Malaysian players. With regard to
playing position, the defenders were found to be the most physically stout, where as midfielders had the lightest body weight.

**Satwanti et al. (1999)** worked on 45 British and 37 Asian adolescent boys and girls. They noted their densitometric and anthropometric measurements. It was noticed that although British boys were taller and heavier than the Asian boys, there was no difference in their body fat content. Asian girls were fatter, lighter and shorter than the British girls. Regression equations were calculated for the prediction of body density and fat free mass from the measurements. It was found that regression equations developed for one ethnic group could be safely used for the other ethnic group for a given skinfold thickness. The Asian adolescents showed higher body density values indicating a greater proportion of fat to be situated subcutaneously in comparison to British adolescents.

**Lawrence et al. (2000)** investigated 60 college athlete girls of Guddapah district to determine the percentage body fat, body surface area. These girls were further divided into two groups as vegetarian and non-vegetarian. Each group carried 30 girls. The age group of the subject was from 16 to 20 years. The study concluded that the non-vegetarians had greater body surface area, percentage body fat than the vegetarians.

**Rajni et al. (2000)** compared Indian male weight lifters with the weight lifters of other countries. The results indicated that Indian weight lifters had less muscle mass, lighter bone mass and greater body weight as than weight lifters of Olympic level. They resulted that the poor performance of Indian weight lifters laid behind their poor body composition.

**Guladi-Russo and Zaccagni (2001)** observed 244 male and 244 female elite volleyball players from the Italian A1 and A2 Volleyball league. the purpose of the study was to examine the importance of somatometric components in relation to their different game roles and levels of performance. The samples were taken during the 1992-93 and 1993-94 seasons. The results showed that the average somatotype for men was 2.2-4.2-3.2 and for women, it was 3.0-3-2.9. Further, they concluded that the physique of athlete in the A1 league was characterized by higher ectomorphy and lower endomorphy and mesomorphy. There was also a slight tendency of male players to greater homogeneity in somatotype within the group at the maximum level of performance. Moreover, somatotype differed in relation to game role in volleyball
players of both sexes. The mesomorphic component was maximal in setters while the ectomorphic components was maximum in centers.

**Kaur et al. (2001)** conducted a study to investigate the predicting excellence in junior elite Indian basketball players. They took anthropometric measurements and found that Indian basketball players were smaller in height and lighter in their body mass and they required somatotype development to be a successful basketball player.

**Ibnziaten et al. (2002)** analyzed the body composition of male school children handball players with an age range of 10-14 years, players from 11 league teams besides the five specific data, they measured eight skinfolds, six lengths, eight heights, thirteen girths and nine diameters. The Matiegka’s method was used to study body composition. The study showed that these players were taller, have more weight and larger span than another athletes, reported in other studies. The percentage of fat mass, from ages 10 to 14, decreased and a change in the distribution of subcutaneous fat was observed.

**Paulo et al. (2003)** observed 23 body builders who were participating in Brazilian body building championship held in 2000. The purpose of this study was to describe body composition somatotype and proportionality of the body builders. The subjects were evaluated moments before the competition according to the specific variables such as weight, stature, skinfolds of biceps triceps, subscapular, chest, medium axillary, suprailiac, abdominal, front thigh, medial calf and muscle girth of biceps and calf and bone breaths of elbow, ankle and knee, in accordance with ISAK methodology. The body builders were between 20 and 56 years old, with body weight between 57.4 kg and 105.8 kg. The sum of the nine skinfold varied between 38.4 mm and 70.2 mm. The somatotype was 1.8-8.1-0.7 which can be classified as a balanced mesomorphic one. The average of body fat was 9.65%, using the Faulkner Protocol proposed by the Brazilian group of kinanthropometry. Fat weight was 7.29 kg. When compared to Phantom, the body builders showed higher body weight (2 =+1.66) elbow girth (2=+5.26) and calf girth (2=+ 1.91). This group of Brazilian elite body builders showed lower body fat percentage and bigger muscular weight when compared to the Ross and Wilson Model (1974) with their body structure similar to the elite international body builders.
Tsunawake et al. (2003) studied 12 women volleyball players and 11 women basketball players who won the championship in the Japan Inter High School Meet. It was noticed that the mean values of the height and the body weight were 168.7 ± 5.89 and 59.7 ± 5.73 kg in the volleyball players and 166.5 ± 7.87 cm and 58.8 ± 6.85 kg in the basketball players. The mean percentage fat was 18.4 ± 3.29% in the volleyball players 15.7 ± 5.05% in the basketball players, and was similar to the reported values in elite adult players. There was no significant difference observed in any measured item of the physique, skinfold thickness and body composition between the volleyball players and basketball players. It was also noticed that the female volleyball players and basketball players had the physical abilities needed to win the championship in the Japan Inter-High School Meet.

Alburquerque et al. (2005) examined Zamora Football Club team of the Spanish football league, along one season. Seventeen anthropometric variables were studied, together with the percentage of fat according to the Carter formula and body composition. The results showed a suitable anthropometric development along the season. Body weight and the body mass index decreased along the period studied with the exception of the suprailiac fold, fat folds decreased as from the first measurement. Fat weight declined, significant differences being observed between the measurement made at the end of the season and the previous measurements taken. Further a discrete increase in bone and muscle weight was observed.

Chauhan and Chauhan (2005) conducted a study on 40 college volleyball players of Kurukshetra University. They studied various body measurements i.e. height, sitting height, trunk length, upper and fore arm length, footlength and girth of shoulder, chest, abdomen, hip, thigh and diameter of biacromial bitrochantric, femur bicondylar and skinfolds of biceps, triceps, subscapular, suprailiac, mid axillary. It is necessary to have strong arm for volleyball players to perform skills such as blocking, smashing, serving and receiving, so the object of this study was to know the relationship between the anthropometric variables and explosive arm strength. The data showed that anthropometric variables have positive and significant correlations with arm strength of volleyball players. Further, they 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
Chauhan (2005) in his study under title “Assessment of explosive leg strength of college volleyball players as related to their anthropometric variables” observed forty volleyball players. The following conclusions had been drawn

1. Age, body weight, height, sitting height, trunk length, leg length, lower leg length, total arm length, foot length and foot breadth have positive and significant correlation with explosive leg strength of volleyball players.

2. Shoulder, chest, abdomen, hip, thigh and calf circumference have positive and significant correlation with explosive leg strength of players.

3. Body diameters i.e. biacromial, bitrochantric, femur bicondylar and ankle diameters have positive and significant correlation with explosive leg strength of volleyball players.

4. Biceps, triceps subscapular, suprailiac, mid-axillary and thigh skin fold are positively and significantly correlated with explosive leg strength of players.

5. Body composition variables i.e. fat percentage, fat weight and lean body mass are also correlated significantly with explosive leg strength of college volleyball players.

Kumar and Ghai (2005) studied 28 women judokas, who were participating in all India Inter University Judo Championship, held in Dec-Jan, 1999-2000. The test was conducted in seven weight categories of women judokas. The winners of first, second and third places where tested for back and leg strength and body composition variables. It was concluded that the body composition played a significant role in strength and performance, because it was found that the player, who was found to have more amount of fat had given less performance and vice-versa.

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 total of 58 players were divided into A and B group and were assessed for physical characteristics, Maximal Treadmill Test and 30s All Out Test. The results showed that centres were significantly taller and heavier (203.9 ± 5.3 cm 103.9 ± 12.4
kg) than forwards (195.8 ± 4.8 cm and 89.4 ± 7.1 kg) and guards (185.7 ± 6.9 cm and 82 ± 8.8 kg) 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.

**Jaskaran and Rajinder (2006)** worked on winner and non winner athletes. They studied 50 winner and 50 non winners athletes, who participated in inter college competitions during the year 2002-2003. They noted twelve kinanthropometric measurements as body height, weight, circumferences, skinfolds. The results revealed that the winner athletes were found to be taller and lighter in weight with lesser value of hip and calf circumferences. All skinfolds were also found to be thin in winner athletes. However, statistical significant differences were found only in hip circumferences and biceps skinfold. In case of height winners athletes had average of 177.5 cm whereas non winners were 176.92 cm and weight of the winners athletes were average 72.46 kg and non winners had 72.93 kg.

**Sorojini (2006)** examined the 31 Meitei women weight lifters of state, national and international level and compared them with 100 Meitei women non-athletes in respect of physical structure. In this study 21 anthropometric variables were studied. It was found that weight lifters had significantly shorter stature with shorter upper and forearm length than the non-athletes. They also had significantly heavier body weight, broader breadth measurements of hand, bi-acromial, bi-iliocristale, bi-trochantric and bigger girth measurements of upper and forearm, normal chest, thigh and calf than non athletes. Further, they had heavier body weight, larger proportion of bi-iliocristale, bi-acromial breadths and limb girths than non-athletes

**Bandyopadhyay (2007)** evaluated 82 volleyball players and 45 football players and 50 sedentary males from West Bengal of 20-24 years. He evaluated and compared anthropometry and body composition, skinfolds, circumference, body fat percentage and endomorphy, All were significantly higher among sedentary persons but lean body mass and mesomorphy were significantly (P<0.001) 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 (P<0.001) value of percentage fat than the sports persons.

**Demuth et al. (2007)** worked on national field hockey players of China, Malaysia, Poland and Switzerland to know the morphological differences of these players. It was noticed that in comparison with non-practising population the field hockey players were shorter, slimmer and their skeletons were much heavier. Body height and body mass of European and Asian competitors differed significantly. The Chinese competitors, the best in the championship, were characterized not only by the lowest body height and body mass, but also by the most massive skeleton. The given information about the body build describes the player’s somatotypes. Although, all the groups under study had mesomorphic body build, the Chinese players had the highest values of those characteristics. The Swiss players who stood last in the ranking had the lowest values of the analyzed characteristics. This suggests that the morphological factor is one of the determinants which facilitate the selection process and success in sports. Thus, the properly realized training process should be supported by many specialists including anthropologists.

**Mariko et al. (2007)** studied 6 handballers, 7 basketballers, 8 volleyballers aged from 19 to 22 years. All of these ball game teams were at top level in university of Japan and all subjects were the regular players in each team. The subjects were only women college players. The objective of this study was to compare the physique and motor performance of the college women players. They found, 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 with 168.3 ± 6.43cm and the basketball players were shortest with 163.8 ± 5.69cm.

**Grigoris et al. (2008)** carried out a study on 163 elite female volleyball players. Body weight, height, breadth, girths and skinfold thickness were measured to know the morphological characteristics of these competitive female volleyball players. The study 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, (sum of five skinfolds 51.8 ± 10.2mm, percent body fat 23.4 ± 2.8) was higher than that of reported in other studies. These volleyball players had balanced endomorphs (3.4-2.7-2.9). Significant differences were found among players of different playing positions which were interpreted by their positions which were interpreted by their varying roles and physical demands during the volleyball game.

Marrin and Bampouras (2008) conducted study on fourteen elite female waterpolo players to know the physiological and anthropometric characteristics of these players within the periodized training years. A repeated measures ANOVA revealed significant differences between testing sessions for body mass (F3,15 = 4.025 P = 0.028), body fat (F3,5 = 9.194, P = 0.001). No statistically significant differences were found for any other anthropometric variables. The study showed that changes in anthropometric characteristics and performance parameters of elite female waterpolo players over a periodized training year occur with no changes in laboratory based physiological measurements. Further, they stated that the waterpolo season generally resulted in significant reductions in body mass as well as body fat percentage. Body fat is largely seen as a disadvantage in many sports. In waterpolo, it has been suggested that body fat may not be as hindering as in other sports, because it helps buoyancy.

Pui and Hendrik (2008) analyzed six elite Kenyan distance runners. It was observed that the slim limbs of Kenyan distance runners may positively contribute to performance by having a low moment of inertia and thus requiring less muscular effort in leg swing. The short ground contact time observed may be related to good running economy since there is less time for breaking force to deaccelerate forward motion of the body.

Zapartidis et al. (2008) noted body height, body mass, arm span, palm length and opening of 181 female young handball players. Their mean age was 14.12 ± 1.09 year and playing experience was 3.41 ± 1.67 years. The purpose of this study was to define and evaluate the differences in anthropometric characteristics between the playing positions in young female handball players. It was noticed that the back players were the tallest (1.68 ± 0.05cm) with the largest arm span (170.56 ± 7.10cm), largest palm opening (21.41 ± 1.09cm) and largest palm length (18.31 ± 0.85cm). Wing players
were the shortest (1.59 ± 0.06m) with the least weight (51.39 ± 6.10kg) the lowest BMI (20.33 ± 1.79kg.m⁻²) the smallest palm opening (20.42 ± 1.19cm) and the smallest palm length (17.33 ± 0.80cm) among all the players. Whereas pivot players had greater body mass (63.99 ± 6.99kg).

Ali and Sharma (2009) carried out a study on 85 inter-college level football players and 80 inter-university level football players to evaluate anthropometric measurements of these players. The results indicated that there were statistically significant differences P<0.05 in body weight (t = 2.14), lower extremity height (t=2.54), and highly significant difference P<0.01 in femur biepicondylar diameter (t=3.71) between medalist of Inter College and Inter University football players and significant differences P<0.05 in body weight (t = 2.62), BMI (t = 2.21) chest circumference (t = 2.76), hip circumference (t = 2.70) and highly significant differences P<0.01 in thigh circumference (t = 3.79) femur biepicondylar diameter (t = 3.88) between non medalist Inter College players and non-medalist Inter University football players. The mean value of height of Inter University medalist was 170.69cm where as Inter College medalists were 173.03 and in body weight Inter University medalists were 59.52 kg and Inter College medalists were 63.4kg.

Fabio et al. (2009) Studied 20 male and female junior badminton players, playing in Brazilian team. Body weight, height, seven skinfolds thickness, diameter, circumferences were assessed to know the anthropometric profile of these players. The results showed significant differences in this study regarding male and female players were, body weight (68.0 ± 7.8 and 61.74 ± 6.85kg) height (172.4 ± 0.5 and 163.8 ± 0.3cm) the sum of seven skinfolds (83.21 ± 22.02 and 131.58 ± 29.36) femoral diameter (9.9 ± 0.39 and 9.0 ± 0.46) humeral diameter (7.0 ± 0.33 and 6.8 ± 0.24) and no significant differences were found in thigh circumference (58.9 ± 3.13 and 58.38 ± 4.15) calf circumference (35.7 ± 1.77 and 35.11 ± 3.26) respectively.

Joksimovic et al. (2009) analyzed 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 ± 5.94 cm) 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.

Milivoj and Marko (2009) worked on 31 waterpolo players. They were all Serbian National Team members and selected according to their field position. The purpose of this study was to define basic anthropomorphological characteristics of these top senior waterpolo players according to their field position. The body height, body mass, Body mass index and Body surface area were evaluated. The data showed that there was statistically significant difference between the estimated variables in the function of player’s position in the tested sample. In body mass at the level (F = 3.97, P value = 0.018), body height (F = 6.10, P value 0.003) and in Body surface area (F = 5.03, P value = 0.007).

Soh et al. (2009) took height, body mass and body fat of thirty three Malaysian women basketball players and thirty two net ball player to compare the physical profile of these players. The subjects were divided into two groups based on their playing performance (i.e. seniors, juniors and reserves players) and position wise (i.e. Forwards, centers and defenders). The percentage of body fat was determined by means of skinfold measurements at seven different locations. It was concluded that there were significant differences in body fat percentage between basketball players and netball players (P<0.01). The senior basketballers were reported to have the lowest body fat percentage as compared to other basketball players and netball players while for the playing position, defence position basketball players were the shortest and have the lowest body fat percentage as compared to other playing positions. Finally, it was found that the basketballers had better physical advantage as compared to the netball players.

2.2 STUDIES RELATED TO JUMPERS AND THROWERS

Cureton (1951) analyzed 22 athletes of United States and concluded that the jumpers, vaulters and hurdlers were relatively slim in skeletal build and were typically taller with longer legs and shorter trunk. They also had relatively great leg length/trunk length and relatively large fore leg length/ thigh length. The shoulder width / bi-iliac hip width index was shown to be important for differentiating javelin throwers from
other types of athletes. The typical throwers were those with greater arm span/height and greater upper arm length/fore arm length.

**Parnell (1951)** conducted a study on university athletic club athletes. The study revealed that the javelin throwers, discus throwers and shot putters were tallest. The subischial length was shortest among controls, slightly greater in sprinters, long distance runners, hurdlers and jumpers and greatest in the small group competing with discus, javelin and shot put. It was observed that all groups of athletes taller than the control group.

**Peres et al. (1954)** investigated the anthropometric variables of top ranking athletes. It was noticed that the throwers were tallest and they were to be benefitted most from their height. The correlation between the relative upper limb length, shoulder breadth, chest circumference (with stature) and performance was positive and significant in the case of throwers.

**Tanner (1964)** worked on the Rome Olympic athletes. He measured their body size, length, girth, proportion and amount of tissue in limbs. The study showed that different athletes of different events show different body measurements. The data showed that the high jumpers were tall athletes, they had the longest legs relative to the trunk than all athletes. The triple jumpers, long jumpers and pole vaulters were within the range of high jumpers for most measurements and proportions. The pole vaulters had distinctly broader shoulders in relation to trunk length than track athletes, The throwers of discus, shot, javelin and hammer were taller and heavier, with longer arms in relation to their legs. They had broader shoulders and broader hips even for their trunk size. The discus throwers were the largest of all athletes. Their arms, in particular were exceptionally big, being not only broader in both muscle and bone, relative to the muscle and bone in the legs, but also longer than the legs. The shotputters were also very large and muscular men and had also long arms. The throwers as shot putter, discus thrower, javelin thrower and hammer thrower had somatotype around 3-6-2.

**Westlake (1967)** carried out a study on 61 female athletes of San Diego. They were divided into four groups. Heath- Carter method of somatotype was used to compare them. The study showed the mean somatotype for each group was as jumpers 3-3-4.5 and the throwers 5-4.5-2. Thus throwers were heavier than the jumpers. They were
more endomorphic, more mesomorphic and less ectomorphic as compared to jumpers. High endomorphy and mesomorphy are assets to the throwers. Thus, body mass is important in throwing events.

**Eiben (1972)** worked on 125 women athletes who were participating in the European Athletic Championship. In this study investigator also evaluated throwers and jumpers. The results indicated that the women long jumpers were smaller. Their trunk was longer and the lower extremities shorter than those of the high jumpers. As opposed to high jumpers, the lower legs of the long jumpers were very long. The high jumpers were taller. Their trunk was relatively short and the lower extremities rather long. The women throwers were tall, heavy and muscular. They had longer lower extremities. The shot putters had the most muscular extremities among all the women athletes. The women discus throwers were the tallest and the heaviest among all the women athletes. Their lower legs were relatively long and their thighs relatively short. Their upper extremities were long and strong. The women javelin throwers weighed least among all the women throwers.

**Malhotra et al. (1972)** carried out a study on track and field athletes. It was concluded that track athletes and jumpers have higher lean body mass with less fat content than the throwers. The jumpers and throwers had strong muscle power where as throwers were tall and heavily built and strong in arm and shoulder muscle strength.

**Muthiah and Venketswarlu (1973)** investigated the Indian field athletes and found that the throwers were heavier, taller and older than other athletes. Where as jumpers and hurdlers were taller and heavier than sprinters but were shorter and lighter than the throwers.

**De Garay et al. (1974)** observed the Mexico Olympic athletes and concluded that the track athletes somatotype as 1.5-4.3-3.5. The throwers whereas clearly more endomorphic and mesomorphic. The jumpers, pole vaulters, javelin throwers and decathelete men had low average skinfolds similar as track athletes, whereas throwers had a higher mean and wider range. The range in endomorphy is, therefore 1.5 to 6.0 units. In mesomorphy the values were high with a range between 5.0 and 9.0 units and in ectomorphy they were uniformly low, ranging from 0.5 to 2.5 units. The pole vaulters, jumpers, javelin throwers and decathelete men were not different from each
other in endomorphy, but the jumpers were less mesomorphic and more ectomorphic than the javelin throwers and decathletes. Thus, with respect to the track analysis, sprinters were more endomorphic and mesomorphic than those of other events, except walking and less ectomorphic than others. Walkers were more mesomorphic than long distance runners. In the field events, shot, discus, hammer throwers were more endomesomorphic and less ectomorphic than those of other events. They found that the throwers were considerably heavier than other group of field events. The throwers had significantly broader shoulders and longer trunks than other field athletes. They also mentioned that the hips of the jumpers were narrower than throwers.

**Fahey et al. (1975)** studied 5 world class shot putters. It was found that the average height of these athletes was 188.2 cm, lean body mass was 93.9 kg and they had 7.1 mesomorphic component.

**Sidhu et al. (1975)** noted the upper arm roentgeno grounds and some kinanthropometric measurements of 22 throwers and compared with 45 normal non-athletes. The throwers were found to be significantly taller, heavier and had greater circumference and skeletal measurements. The lean body mass was greater in the throwers than that of the control sample. Roentgenogremmetric assessment indicated that the constant throwing exercise had resulted in a greater development of the upper arm muscles, distinctly the triceps.

**Bush and Weiskpot (1978)** conducted a study on shotputters. It was found that explosive quickness was the major factor for the athlete to move across the circle and get into the proper throwing position to use his power in putting the shot. They also concluded that large and heavy women have been more successful as shotputters than the smaller women because strength is relative to body mass.

**Guimaraes and De Rose (1980)** carried out a study on 345 participants in the 8th Brazilian Student Games held in Porto Alegre in December 1976. In all, 218 men and 127 women under the age 18 years were included in the study. In order to present the results, the events were classified into the four groups such as running and walking, jumping, throwing and decathletes. The mean of ages, height, weight and somatotype were studied. The result showed that the high jumpers were average 17.26 years old in age, 66 kg. in weight, 181.8 cm in height and means of somatotype was 1.8-3.4-4.4. The long jumpers were 17.61 year old, 63.5 kg in weight, 177.2 cm in height and
means of somatotype was 1.8-3.9-4. The triple jumpers were 17.85 years old, 63.10 kg heavy, 178.8 cm long and mean of somatotype was 1.6-3.3-4.3. Whereas pole vaulters were 18 years old, 60.30 kg heavy and 174.6 cm long and mean of somatotype was 1.9-4.6-4.3. In throwers, the discus throwers were average 17.66 years old in age, 81 kg in weight, 179.6 cm in height and mean of somatotype was 3.1-5.9-1.9. The shot putters 16.96 years old, 84.10 kg heavy, 178.7 cm long and mean of somatotype was 3.2-6.4-1.3. The hammer throwers were 17.78 years old in age, 84.10 kg in weight 179.6 cm in height and mean of somatotype was 3.4-6.3-1.2 whereas javelin throwers were 17.66 year old, 76.70 kg heavy 178.7 cm long and mean of somatotype was 2.7-5.5-2.2. Further the analysis of the results showed that the Brazilian male student athletes presented as general characteristics (73.7%) a slightly high endomorphy component. Only in javelin throwing was the difference in rating more stressed. This means that the sample studied showed a large amount of adiposities. The result found with regard to mesomorphy showed this component to have a lower rating (89.5%) than the reference students that were used. For mesomorphy, one noticed that the rating differences were considerably more accentuated than for endomorphy. This means that the participants in the Brazilian School Games of (1976 athletics) presented an inferior musculoskeletal structure and for ectomorphy, after an analysis of the weight and stature of Brazilian athletes, it was observed that this component presented a considerably higher rating (84.2%), as a result of the fact that weight was low in relation to stature.

Thorland et al. (1981) examined 145 male and 133 female adolescent participants in National Meet Competition in the sports of track and field, gymnastics, diving and wrestling. The objective of the study was to determine body composition and somatotype in Junior Olympic Competition to evaluate the structural characteristics concomitant to high proficiency in various athletic activities. The most frequent differences within either the male or female Junior Olympic samples involved the performers in throwing events (shot put, discus and javelin), who were taller, heavier, fatter and unique somatotype when compared to all or most other competitors. Difference in body composition characteristics were also noted when junior Olympians were compared with other adolescent athletes or non-athletes.

Carter et al. (1982) investigated anthropometric characteristics of Montreal Olympic Athletes. The study revealed that the jumpers were heavier as compared to sprinters
and long distance runners, the formers had larger calf girth than the latter. They also had larger lower extremities length than the sprinters and larger sum of 6 skinfolds than the distance runners.

**Morrow et al. (1982)** conducted a study to know the relationship in anthropometric characteristics, strength variables and physical performance performance of 49 American discus throwers, hammer throwers, javelin throwers and shot putters who were participating in pre-Olympic training camp. It was observed that there were significant differences in kinanthropometric characteristics and strength variables among the different groups of throwers.

**Thomas et al. (1983)** in their study Twenty-four collegiate distance runners and twenty power athletes (sprinters and jumpers) of various success levels were tested on a number of physiological and psychological parameters. Subjects were male volunteers, ages 17-22 years, from the University of Kansas Varsity track and field team. All subjects had been training for several years. The multiple regression analysis indicated that the combination of physiological and psychological variables could explain a large percentage over 80% of the variation in jumping performance. The percent fat, body weight were the strongest predictors of power event performance. The weight of the jumpers was 73.16 ± 6.45 and the percentage of fat was 4.6 ± 2.0.

**Ross and Ward (1984)** analyzed Olympic athletes and it was noticed that the jumpers were lesser in weight than sprinters. The high jumpers had no proportionally different length and breadths but had proportionally smaller girths and one smaller and two larger skinfolds. The long jumpers were proportionally shorter in the arm and longer in thigh lengths when compared to the sprinters. They were smaller in humerus and femur breadths, thigh and calf girth and three of the four skinfolds. The triple jumpers were not proportionally different in length and breadths, except for biacromial breadth where they were narrow. They were smaller in all proportional girths and one of the four skinfolds. The throwers had proportionally longer trunks and thighs and consistently larger breadths, girth and skinfold thickness than the sprinters. No significant differences had been found among shot, discus and hammer throwers. The javelin throwers had shorter thigh consistently larger breadths and larger arm girths.
than the sprinters. They were as lean as the sprinters except for larger triceps skinfolds.

Sodhi and Sidhu (1984) observed that the long, high and triple jumpers were taller but lighter in weight with proportionately longer extremities and shorter trunks than other field athletes. The results indicated that throwers were more muscular and had greater lean tissue area and total body fat. When Indian players were compared with the Olympic athletes of 1960 and 1968, the study shows that the jumpers, polevaulters and decathletes did not dominate in endo-mesomorphy. The Indian athletes were proportionately slender in skeletal build. The Indian pole vaulters were taller with longer lower extremities than but not as long as that of the other jumpers. They had greater mesomorphy but lesser fat than the other jumpers. The Indian discus, hammer and shot put throwers were greater in all anthropometric measurements. Indian discus, hammer and shot put throwers were proportionately heavier, with a longer trunk, longer upper extremity, broader shoulders and hips, and a larger chest. The throwers possessed greater knee width and were more muscular, with greater lean tissue area and the total body fat. In somatotype components. The Indian throwers except javelin were considerably more endomorphic and less mesomorphic than the Olympic athletes of 1960 and 1968. The javelin throwers have the shortest stature among all field athletes. Like the endomorphic and mesomorphic components of somatotype, amongst Indians there was a gradient of decreasing body fat from discus, hammer and shot put throwers to javelin throwers to pole vaulters and the long, high and triple jumpers. All athletes in India were leaner on the average than the athletes of the respective field event from Olympics.

Doherty (1985) stated that the discus style is most easily and effectively learned when the athlete is shorter but powerful with great quickness and agility. A circle only seven feet wide greatly handicaps the tall and heavily muscled athlete. The rotation technique actually favours female athlete because the lower center of gravity makes spinning easier and generates much less centrifugal force requiring resistance and angular velocity that helps to overcome a woman's natural deficiency in power.

Calderia et al. (1986) examined university female players of Brazil and Javelin female throwers. The study showed that both groups were less mesomorphic. The
somatotype of both groups was as university players 3.2-2.7-3.0 Javelin female thrower 3.7-3.0-3.4

Sodhi (1986) worked on field athletes and the results indicated that the fat folds were considerably greater in throwers. On an average the throwers had consistently thicker fat folds than all other athletes. The discus throwers, hammer throwers and shot putters showed the maximum average value of fat folds at all measured sites. The jumpers were fallen with in the range of track athletes in the pattern of subcutaneous fat distribution.

Uppal and Ray (1986) studied fifteen male shotputters and fifteen male javelin throwers of college level. The results showed that the arms strength, grip strength and explosive legs strength were significantly relative to performance in shotput. There was a significant relationship between arms strength, explosive leg strength and lean body weight to performance in javelin throw. The relationship of selected body composition variables namely body density, lean body weight and percentage of fat to performance in shot put were not significant. Grip strength, body density and fat percentage were not significantly related to performance in javelin throw.

Doxey (1987) worked on athletes and reported that in athletic activities where body weight moves vertically or horizontally over the ground, there is a relationship between body fat levels and performance e.g. percentage body fat showed a strong negative correlation to 40 yard dash speed and vertical jump height.

Mokha and Sidhu (1988) investigated 157 athletes. They took 42 throwers, 35 jumpers and 80 runners. The subjects were taken from the different state level, intervarsity level and district level competitions. It was noticed that the throwers were significantly fatty than jumpers, but there were no major differences observed between jumpers and runners.

Sharma and Shukla (1988) reported that jumpers were more ecto-mesomorphic with somatotype of 1.6-3.8-4.6 and the throwers of discus, hammer and shot-put were more mesomorphic with somatotype of 3.5-6.5-1.2 where as sprinters were greater in ectomorphy and mesomorphy with somatotype of 1.6-3.8-4.7.

Guennadi (1990) studied the anthropometric and physical fitness parameters for high jump with performance. The results showed that only tall persons with less weight
were capable of achieving high results. Furthermore, he stated that the height of the sportsperson is an essential component and therefore much importance must be given to this parameter during talent search.

**De et al. (1991)** investigated the south Asian athletes and found that the mean height of throwers were $(179.96 \pm 1.49\, \text{cm})$ maximum and the long distance runners were $(162.82 \pm 2.61\, \text{cm})$ the shortest and in body weight throwers were $(92.27 \pm 3.81\, \text{kg})$ the heaviest and the long distance runners were $(50.41 \pm 2.58\, \text{kg})$ the lightest.

**Holings and Robson (1991)** studied 38 elite young male athletes to analyze body build and performance characteristics. The athletes were classed into 4 groups depending on their chosen events sprinters and hurdlers, jumpers, throwers, and middle distance runners. Performance in vertical jump, the margaria stair run, and the wingate test were investigated. Analysis of variable showed the throwers to be significantly different from other group in body build and middle distance runners to be significantly different from other group in performance characteristics.

**Sodhi et al. (1991)** noticed that average bone mass of the discus throwers, hammer throwers and shot putters was 13.01 kg, muscle mass was 38.22 kg, and body fat percentage was 19.01% whereas bone mass decreases gradually in a gradient from 400m onwards upto 5000 m and 10000 m.

**Pal and Murlidharan (1992)** found in their study that relationship between performance in long jump and weight of the subject was not statistically significant. The data showed that the body structure of an athlete had a vital influence on their physical performance. The coaches and physical education teachers while selecting their athletes for participating in any competition give due consideration to the technique possessed by the athlete and at the same time they provide due weightage to various anthropometric measurements.

**Sullivan et al. (1994)** conducted a study on 87 adolescent pole vaulters of age group 13-18 years to determine the anthropometric characteristics of skilled adolescent pole vaulters and to examine the strength of anthropometric and physical performance variables in predicting vaulting performance. The vaulting height of the subjects ranged from 1.98 to 4.72m. The vaulters were classified as ectomorphic mesomorphs with an average somatotype of 1.6-4.2-3.5 (s.d. +/-0.38-0.94-1.00). One way analysis
of variance showed that while measures of stature, physical performance and vault performance significantly increased (p<0.05) across age groups; somatotype and sum of skinfolds remained stable. Stepwise regression analysis showed the best predictor of vaulting performance was hand grip height (R2 = 0.78, p<0.05). Correlation analysis showed that grip height was strongly correlated to vault height (r = 0.88), age (r = 0.72), body mass (r = 0.71), standing long jump (r = 0.69) running speed (r = 0.69), biceps girth (r = 0.66), standing height (0.65), calf girth (0.61) and pull-ups (r = 0.44). In addition, they resulted that the somatotype of skilled young pole vaulters is similar to that of junior Olympic and adult Olympic vaulters.

Amatya (1995) studied 273 Nepalese athletes during the National Army Meet and SAF games of Kathmandu. Biceps, triceps, subscapular, suprailiac, thigh and calf skinfolds were measured and concluded that discus throwers, hammer throwers and shotputters had thickest skin fold values and the marathoners had the thinnest at all the sites.


In the study thirty throwers were selected as subjects from the University Athletic Meet of Kurukshetra University, Kurukshetra. Thirty two body measurements were taken with the help of anthropometer, steel tape, vernier caliper and skin fold caliper, according to the instructions of Weiner and Lourie (1969). In extent, it was concluded that throwing performance of the subjects was measured in terms of performance in putting the shot. The Product Moment Method for inter co-relation and Wherry Do Little Method for calculating multiple correlation and developments of regression equation of the prediction of performance were applied. The measurements i.e. height, leg length, fore-leg length, total arm length, upper and forearm length, circumferences i.e shoulder, chest, abdomen, hip and arm, body diameters, i.e. biacromial, bicristal and elbow diameters and skin fold measurements i.e. biceps, subscapular suprailliac and calf skin folds have been found to possess positive and significant correlations with throwing performance at 1% and 5% levels respectively. Among body composition variables i.e. fat percentage, fat weight, lean body mass had positive and significant correlations but body density has negative and significant correlation with throwing performance at 5% level. The multiple correlation of body weight, height and total arm length with throwing performance is positive and highly significant.
(R=.935). The size of the multiple correlations is quite sufficient and hence the regression equation developed can be used for the prediction of throwing performance of the athletes.

**Kruger (2004)** worked on Javelin throwers. The purpose of this study was to describe the body composition and somatotypes of international male elite javelin throwers and to identify which variables distinguish the world’s elite javelin throwers from the sub elite throwers and which variables contribute to their performance. Elite javelin throwers were found to have an average body mass of 97.0kg, stature of 187.5cm., percentage body fat of 11.9% and percentage muscle mass of 40.4% The javelin throwers had an average value of 11.2kg for skeletal mass and expressed as a percentage of 11.7%. The average humerus length was 35.5 cm with forearm 28.7 cm. The Javelin throwers had an average bi-iliocristale breadth of 31.9cm, bi-acromial breadth or 45.5 cm. The average wrist breadth 6.0 cm ankle breadth 8.1cm, femur breadth 10.2 and humerus breadth 7.4cm. The Javelin throwers had an average flexed girth 38.3cm, forearm girth 30.5cm, thigh girth of 64.1cm and calf girth 40.8cm. The average sometotype for the javelin throwers were 2.5- 5.9-1.4. The forward stepwise discriminant analysis found the variable that best discriminant between the two groups to be age (F = 10.53, P<0.05), body mass (F = 3.97) and percentage muscle mass (F = 2.33).

**Langer (2007)** conducted study on high jumpers. The main objective was to analyze the development of somatic prerequisites in the high jump globally, to describe the morphological character of high jumpers and to demonstrate the relationship between sports performance in this event and mutual interaction. Body height, weight, skinfold, bones and girth of arm and calf were measured. Subjects were divided into 5 sets as the jumpers of both of males and females of the years of 1983-1984, 1985-1986, 1989-1991, 1995-1996 and 2002-2005. Results showed that the average body height of the tested male high jumpers (h=1.92m) did not differ much from the first ten world male jumpers and were shorter only by 0.02m. The tested female high jumpers were as tall as the best female high jumpers in the measured world tables (h=1.78m). The body weight average values with the measured male and female high jumpers were approximately the same in some stages of the research. The last measurement of woman (2002-2005) when the average body weight decreased considerably in comparison with the previous periods was an exception. The
particular somatotype components show a tendency to increase (3.4-3.7-4.2), which corresponds to the category of mesomorphic ectomorphs with groups of high jumpers. Particularly, in the last two stages of measurements the dominance of the ectomorphic component (51%) was evident. Study revealed the combination of components 3.4-3.8-4.2 for the female high jumpers. Thus, it was the same category as with men mesomorphic ectomorphs. Most of the athletes did not show the extreme mesomorphy and were placed in the graph from mesomorphic ectomorphs through balanced mesomorphs up to endomorphic mesomorphs.

**Sumanta et al. (2008)** worked on 17 shot putters, 10 hammer throwers, 15 javelin throwers and 11 discus throwers who participated in the 64th All India Inter University Athletic Meet held at Jamshedpur in the year 2004 and crossed the qualified standards of 12 meters in shot put, 38 meters for discus throw and hammer throw and 55 meter in javelin throw. They measured 14 anthropometric measurements of height, arm length, upper arm length, forearm length, upper arm girth, forearm girth, chest circumference, shoulder width, leg length, upper leg length, lower leg length, thigh girth, calf girth and percentage of fat. It was observed that among the selected parameters only a few parameters in every event were found insignificant to the performance at 0.5 level.

**Pritam et al. (2009)** carried out a study to find out the differences among various groups of intervarsity male throwers and long distance runners. The study was conducted on 120 interuniversity long distance runners and throwers. The height, weight, body mass index and percentage of body of each subject were taken by using standard techniques. It was found that long distance runners were found shorter as compared to throwers. In throwers, shot putters were found to be the tallest, followed by discus throwers and javelin throwers. In running events, cross-country athletes were found lightest among all groups. The BMI was found maximum in throwers (which were considered overweight due to their less height and more weight) followed by long distance runners. Maximum BMI in throwing events was noticed in shot putters followed by discus throwers and javelin throwers. In long distance runners, the maximum BMI was noticed in 5000 m, followed by 10,000 m and minimum in cross country athletes. The percentage fat was found maximum in throwing events (Javelin throwers have less percentage body fat, followed by discus throwers and shot Putters).
Ragad Al (2010) studied 30 javelin throwers, who participated in King Hussein sport championship. The objective of the study was to know the relationship of certain physical characteristics and anthropometric measurements with performance of javelin throwing event. Results of the study indicated that there was a relationship with statistics significance between the height, length trunk, length of arm, length of forearm, length of leg, length of thigh, perimeter of chest, perimeter of forearm, perimeter of upper arm and performance level of javelin throwing. He also found that there is no correlation between the perimeter of thigh, length of palm and performance level of javelin throwing.

Terzis et al. (2010) worked on well trained hammer throwers. Their age was 25.8 ± 5 years, height 1.85 ± 0.04m, body mass 116 ± 6kg, BMI 34.1 ± 1.6 Kg m⁻². All of the athletes had participated in organized hammer throwing training and competitions for at least five years. The mean hammer throwing performance of the subjects was 72.17 ± 6.40. They also studied eight male physical education students of age 22 ± 1 year, height 1.82 ± 0.04m, body mass 78.5 ± 8.0kg. BMI 23.2 ± 3kg m⁻² as a control group. Dual x-ray absorptiometry was used for body composition analysis. The study revealed that the lean body mass was higher in hammer throwers (85.9 ± 3.9kg vs. 62.7 ± 5.1kg). Hammer throwing performance correlated significantly with lean body (r = 0.81, P< 0.05). These data indicate that hammer throwers have larger lean body mass and larger muscular area occupied by type II fibers, compared with relatively untrained subjects. Further, they stated that the larger muscle mass of the hammer throwers contributes significantly to the hammer throwing performance.