CHAPTER - II

REVIEW OF RELATED LITERATURE

A review of relevant literature to the present study that could be gathered from the libraries of leading institutions of Physical Education and Sports of the region is presented in this chapter. This would help in determining the need and significance of this study. The literature thus collected has been classified into three sections: (a) studies on motor-fitness components and performance; (b) studies on anthropometric measurements and performance; and (c) miscellaneous studies related to the problem. Further, in each section studies have been presented in such a way that the relevant critical literature has been followed by allied peripheral literature, regardless of the chronological order. A brief summary of the literature has been presented at the end of this chapter.

Studies on Motor Fitness Components and Performance

Kela (1984) studied the relationship between speed of movement, agility, shoulder and spine flexibility and performance in gymnastics. Twenty five inter-university women gymnasts from various universities, who came to participate in the Inter-University Gymnastics Competition held at Amritsar in 1984, were selected as subjects.
for this study. The average age of the subjects was 26 years. Rank difference method was used to compute correlations between speed of movement, agility, spine and shoulder flexibility and performance in gymnastics. The findings of the study showed that while there were no significant correlations between speed of movement, spine and shoulder flexibility to performance in gymnastics, agility had a highly significant relationship with performance in gymnastics. The level of significance was set at .05.

Chakravarty (1983) investigated the relationship of leg strength, grip strength, agility, flexibility and balance to performance in gymnastics. For evaluating arm strength, leg strength, grip strength, agility, flexibility and balance the following tests were employed. Arm strength measured by \( \frac{1}{2} (\text{pullups} + \text{dips}) \times \frac{W}{10 + H - 60} \); leg strength measured by leg dynamometer in pounds, grip strength by Monometer in pounds, agility by shuttle run 4 x 10 yard in seconds; spine and shoulder flexibility measured by flexiometer with yard stick to the nearest inches and balance measured by modified bass dynamic balance test in 100 points respectively. From the findings of the study Chakravarty concluded that: (1) arm strength, leg strength and left
grip strength of gymnasts was not found to be significantly related to gymnastic performance; (2) agility of an individual was not confirmed as a factor in developing performance in gymnastics; (3) spine and shoulder flexibility did not contribute towards gymnastic performance; (4) dynamic balance and gymnastics performance showed insignificant relationship; (5) right grip strength was the most important variable that contributed to performance in gymnastics.

Uppal and Gill (1989) conducted a study on a sample of 80 male gymnasts ranging in age from 18 to 33 years belonging to different states of India. The data were collected in the 27th National Gymnastic Championship held at Jabalpur. Each subject was administered four strength tests—arm strength, abdominal strength, grip strength and explosive strength of legs. The relationship of strength to performance in gymnastics was established by computing Pearson's Product Moment Correlation. The analysis of data revealed that performance in gymnastics is significantly related to arm strength ($r = .37$), abdominal strength ($r = .30$), right grip strength ($r = .51$), left grip strength ($r = .47$) and explosive leg strength ($r = .39$). Hence it is possible to predict gymnastic performance on the basis of strength variables. Further the multiple correlation of ($r = .68$)
indicates that in order to predict performance in gymnastics, instead of depending only upon a single variable, all the variables may be given due consideration.

Prestidge (1972) states that a gymnast requires a great deal of strength in almost all parts of the body but specially in the back, legs, abdomen and shoulders. If a gymnast has adequate strength then he can perform all the movements easily and without any strain.

Cumming (1967) states that in four of the six events explosive power and muscular strength are required for approximately 30 seconds as the gymnast controls his total body weight with his hands in either support or hanging position. These demands are such that gymnasts at high level are among the leanest, strongest and most flexible of all athletes.

Bawa (1981) reported that Indian top class gymnasts are found to be more muscular, stronger, flexible and powerful than the poor level gymnasts.

Newton and Robert (1970) emphasise the requirement of flexibility of shoulders, hip and other body parts. They state that a gymnast must be able to do the split front as well as side split with ease. The back must be very strong and flexible in order to work for floor exercises and vaulting. Gymnasts must have extreme range
in the ankle for pointing out toes. The wrist and hand must be very flexible and strong to work on every piece of equipment.

Baley (1977) stated that good flexibility is essential for the development of skills in gymnastics since resistance from muscles, tendons, and ligaments is minimal.

Harre (1979) pointed out that flexibility is a primary prerequisite, both qualitatively and quantitatively, for good execution of the movements. He further stated that lack of flexibility can result in: (a) difficulty in learning new movements; (b) injuries (c) incomplete expression of conditional abilities, i.e., strength, speed, endurance and the complex forms. The importance of flexibility, i.e., ability to execute movements with wider amplitude, is obviously of great importance in gymnastics because of the nature of the sport.

Fukushima (1980) in his review of physical conditioning has mentioned that more than 60% of men's, and about 30% of women's, gymnastic movements involve supporting tasks. Movements on rings, parallel bars, horizontal bar and uneven bars, present many tasks involving suspension such as swings, sudden pushes and holds. Even on floor exercises and the entire take off
stage of long-horse vaulting require muscular strength for an appropriate kick to take off.

Sanborn and Waneen (1969) examined the relationships among standardized and modified balance tests, balance discrepancy scores, balance speed tests, and an Olympic balance beam skill test. Each of the balance variables served as an independent variable in a multiple regression analysis to predict Olympic beam performance. The bass stick test and the Sideward leap test were raised to a height of 3'-11" above the floor to determine the effect that height would have on balance ability. Little relationship among any of the tests was found. Task height significantly affected balance performance in both static and dynamic tests. Neither balance discrepancy scores, nor balance speed tests, efficiently predicted balance beam skill, although one of the speed tasks significantly discriminated between the initial and intermediate beam performances. The most effective combination of predictors of balance beam skill were two tests of dynamic balance - the Sideward leap and the modified Sideward leap.

Sanborn (1973) investigated the relationship of balance test and Olympic balance beam performance. Students (N=94) performed on items of balance at floor level at a height of 3'-11" above floor level,
and balance beam skills and speed tests. Superior balance as measured by simple test did not predict beam skill.

Raising the height of the standardized tests seems to affect the subject's performances, and balance beam performance was more closely associated with dynamic balance than with static balance.

Brennan (1968) compared skilled gymnasts and dancers for thirteen characteristics. Thirteen tests were administered to 18 subjects in each group to measure strength, kinesthesis, balance, flexibility, rhythm, and motor performance. A multi-variate discriminant analysis was applied to determine whether 4 groups (skilled gymnasts, skilled dancers, skilled sport participants, and untrained) participants, could be distinguished from each other on the basis of the measurements. The results established that the 13 variables served to differentiate the 4 groups from each other but not to the same degree. The gymnastic and dancer groups were related to each other but not to the other 2 groups. The sports proficient and untrained groups showed little relationship to the other 3 groups.

Fleishman, Thomas and Monroe (1963) studied the dimensions of physical fitness through a factor analysis of speed, flexibility, balance and coordination tests. Six factors were identified to account for performance
on the thirty performance tests. The factors identified were explosive strength, extent flexibility, dynamic flexibility, gross body equilibrium, balance-visual cues, and speed of limb movement.

Heller (1970) studied the validity of predicting motor educability in gymnastics. This study utilized in experienced college students in learning a pommel horse routine and it was concluded that the IOWA revision of the Brace test scores did relate positively to the rate of learning a beginning routine.

Gill (1983) investigated the relationship between grip strength, arm strength, hand, foot and stepping reaction time to playing ability in badminton. Sixteen male badminton players who participated in the Gwalior District Badminton Championships for the year 1932-83, served as subjects for this study. The variables were grip strength, arm strength, hand, foot and stepping reaction times. A statistical analysis of the data revealed that arm strength, hand, foot and stepping reaction times were significantly related to playing ability in badminton, whereas grip strength and playing ability in badminton were not significantly related to each other. Thus the variables arm strength, hand, foot and stepping reaction times contribute significantly to better performance in the game of badminton, whereas grip strength does not do so.
Alam (1983) studied the relationship of reaction time, agility, and flexibility to performance in running broad jump of the 51 male students from first year degree class of Bachelor of Physical Education of Lakshmibai National College of Physical Education, Gwalior. The product moment correlation method was used to compute correlation between running broad jump and reaction time, agility, and flexibility. The findings of the study revealed that there was significant correlation between dependent variables and independent variables. There was significant correlation between running broad jump and reaction time, and also there was significant correlation between running broad jump and agility, and running broad jump and flexibility. The obtained value of correlation was found statistically significant at .05 level of confidence.

Pinheiro (1983) determined the relationship of strength, flexibility, agility, reaction time, and speed of movement to the acceleration phase in sprinting. Thirty male students, who had been training themselves for sprints during the optional hours and were studying at Lakshmibai National College of Physical Education, Gwalior, were selected as subjects. The reliability of the data collected was established by test-retest method in case of shuttle run, acceleration run, and standing broad jump and in the case of other variables.
The final score was the average of the five readings of the subjects. Within the limitations identified and on the basis of the results of the study, the following conclusions were drawn: (1) The explosive leg strength and the right leg stepping reaction time was significantly correlated with performance in the acceleration phase. (2) The left leg stepping reaction time was not significantly related to the performance in the acceleration phase. (3) The foot reaction time, speed of movement, agility and flexibility were not significantly related to performance in the acceleration phase.

Greenlee (1960) investigated the relationship of selected measures of strength, balance and kinesthesis and bowling performance. Test of leg strength, grip strength, arm and shoulder girdle strength, static and dynamic balance and various measures of kinesthesis including wrist extension, rotatory position of the forearm and forward weight shift were administered to 122 beginning bowlers during the last two weeks of an eight week bowling course. These test results were correlated with an average of the last 6 games bowled. A significant positive relationship was found between dynamic balance and bowling performance.

Crenston (1968) studied the relationship of reaction time, movement time, and visual tracking to
performance in badminton. The data was based on 32 college women enrolled in badminton classes at Smith College. A reaction time movement time device, a pursuit rotor, and the Hiller badminton wall volley test were used. Reaction time, movement time, and visual tracking had no apparent relationship to performance in badminton.

Smith (1969) formed three groups of subjects: 68 fresh players, 11 varsity players and three highly skilled and experienced players in the relationship of volleyball playing ability to scores achieved in the Sargent vertical jump. Vertical jump correlated .35 with the Brady Test, .55 with the judges evaluation, and .50 with a combination of Brady Test and judges evaluation for the fresh players. The 'r' between the vertical jumping ability of the varsity players and a potential playing ability ranking by their coach was -.36. It was concluded that vertical jump is not an accurate predictor of volleyball playing ability.

Gallagher (1970) studied the relationship of agility to performance in women inter-collegiate basketball. The hypotheses that high positive relationships would exist between items of the test (McCanliff Agility Components
Test) and performance were not supported. The lack of evidence to support the hypotheses was attributed to some unexpected peculiarities of the sample and several recommendations were made for continued investigation.

Wharton (1980) studied the AAHPER Youth Fitness Test as predictor of skill development in field hockey. One hundred and seven senior high school girls who had no previous field hockey training were used as subjects. A significant relationship was found between the scores on the youth fitness test and field hockey achievement as measured by the Schmithals-French Field Hockey Achievement Tests.

David (1977) predicted the potential of 67 football players ranging from 18 to 23 years provided subjects for the study. The test battery was set up in six stations. The test battery consisted of motor ability items as well as football skill items. Substantial correlations were obtained between most test items and the test criterion (the sum of T-scores). Size, as depicted by McClay's classification index (CI), had a negative non-significant correlation with the criterion. The discriminative power of the battery was evidenced by the highly significant correlation between the test criterion and the coaching staff ranking of individual
players \( r = .640 \). It was concluded that athletic potential in football can be predicted by testing. In the second part of the study, football teams from three different strata of competition were evaluated on the basis of the test battery. The battery substantiated a step-wise progression between the teams on most items, with significant differences being noted. The test showed validity in that the test criterion (the sum of T-score) was significantly different between the teams.

Hengst (1966) administered the Springfield Beam Walking Test on female university students (32). Following this they had two practice sessions of 4 trials each in walking a 72 ft. balance beam. These sessions were administered 3 days a week and a record was kept of the distance walked by each individual on each trial. Correlation co-efficients and predictive indexes indicated that one administration of the Springfield test predicted with 32 per cent accuracy in balance ability as measured by walking the 72 ft. balance beam after 10 days of practice. At least 6 days' practice on the 72 ft. beam was necessary before the ability to walk the beam could be predicted with more than 50 per cent accuracy.

Preskitt (1968) conducted a study on college students who were unable to perform the skin the cat skill. They were equated, with each being assigned to
follow one of the two devised exercise programs. The results indicated that strength increase was a factor in the performance of the skill but was not the determining factor; that one exercise program (prescribed) was not superior to the other (apparatus exercise) in terms of effecting an increase in strength; that the apparatus exercise program was more efficient in terms of time spent in practice by subjects who were successful in performance of the skill; and that the apparatus exercise program appeared to be the more effective program in terms of the proportion of successful subjects within that programme as compared to the prescribed exercise programme.

Studies on Anthropometric Measurements and performance

Carter et al. (1982) studied the Montreal Olympic gymnasts and concluded that the typical male gymnasts were 25.4 years old, 163.3 cm tall and 63.5 kg in weight. They were smaller than other sportsmen on most variables, except for greater arm girth than hockey players and cyclists. Gymnasts are proportionately larger on upper body breadths, girths and forearm length than others.
Singh (1982) studied gymnasts, swimmers, and footballers. He stated that gymnasts were found to be lightest and leanest of the three groups. The upper arm girth was found bigger in gymnasts as compared to the other groups. The sitting height was found significantly lower in gymnasts as compared to other groups.

Bawa (1981) studied the Indian male national gymnasts and concluded that a gymnast who wants to excell in gymnastics must possess proportionately larger chest, wider shoulders, thicker arms, a smaller waist, and narrower hips.

Le Veau et al. (1974) studied the Japanese and American National Gymnasts and found that the mean height of male Japanese gymnasts (164.3 cm) was five centimetre shorter than American gymnasts (169.6 cm). They observed that the combination of lighter body and relatively greater strength specially in the upper body provides an ideal structure for gymnastic movements.

Salmela (1982) having compared age, height and weight of gymnasts of 1972 and 1976 Olympics games concluded that gymnasts who participated in 1976 Montreal Olympics were younger, smaller and lighter as compared to gymnasts of earlier years.
In a study on 79 college male students who underwent an eight week course in gymnastics, Williams (1979) found that body measurement ratios were correlated significantly with gymnastic ability beyond .05 level of confidence.

Falls and Humphrey (1979) reported a significant difference in height between gymnasts and non-athletes, and placers and non-placer (Placers had 161.54 cm and non-placer had 162.05 cm height whereas non-athletes had 164.08 cm).

Gunney (1973) reported that if two athletes are equally trained with identical body-builds the taller gymnast is at a disadvantage because he or she has a smaller strength-body weight ratio than the shorter gymnast.

Sinning and Lindberg (1972) found that college female gymnasts had a mean weight of (51.09 ± 7.03 kg), which is significantly less than the average college-age women. He further stated that they were also found smaller in skeletal diameters and circumference in the lower trunk and limbs.

Sprynarova and Parizkova (1969) found female gymnasts to be of less height than female swimmers.
DiGiovanna (1943) reported the body measurements of male gymnasts. He concluded that the individual who tended to succeed in college gymnastics was one who, compared to the normal individual, had the following characteristics: The male gymnast was substantially smaller in height, leg length and hip breadth, and substantially larger in arm girth. Gymnasts were described as moderately shorter.

Read (1967) found that the better gymnasts (male) averaged significantly shorter in sitting height and arm span than the other two lower ability groups of gymnasts.

Medved (1966) in a sample size of 6217 adult sportsmen found male gymnasts to be smaller than the average sportsmen (.01 level of significance). In case of women, Medved (1966) studied 596 adult sportswomen and found the female gymnasts were smaller than the other women sports participants at the 0.05 level of significance.

Christensen (1979) reports that the gymnasts with small and light body size appear to have some distinct advantages over the taller and heavier body structure all other factors being considered equal. One cannot ignore the fact that body size may be a significant factor in the successful performance of a gymnast.
Bird (1979) studied the anthropometric measurements of the male gymnasts. He described that the gymnasts were well muscled with a light skeletal structure which he claimed as a mechanical advantage for small body size. He found the girth of the chest, biceps, thighs and abdomen to be above average and gluteal and calf measurements below average. Thus the gymnasts were above average in the upper body development and below average in the lower body measurements.

William (1964) determined whether a relationship of certain body proportion to success in the sport of gymnastics exist. For this study ten body measurements each were taken of 79 college men and ratios were computed. The subjects were given an eight week course in gymnastics and tumbling. Five of the body measurement ratios showed significant correlation with gymnastic ability. An $r'$ of .64 was calculated between a combination of these five body measurement ratios and gymnastic ability. Although the $r'$ did not produce a high enough correlation for selection of individual squad members, it might serve for group classification in Gymnastics at the initial stages.

Sharma, Chauhan and Parkash (1937) conducted a study on body measurement of endurance runners of National
games between the age range of 18 to 19 years. Out of total 40 subjects, twenty were national school endurance runners and the other twenty were non-sportsmen (control group) who never took active part in any event or game at any age level. The subjects were measured for twenty four body measurements including linear measurements, circumferences, diameters, and skinfolds. For comparing the physical characteristics of endurance runners and non-sportsmen, the mean standard deviation and t-test were utilised. From the results of the study following conclusions were drawn: (1) endurance runners for the national school games were found to be shorter and lighter in body-weight with low fat contents than average youngman, but equal in lean body mass and more in body density. (2) The skeletal measurements, i.e. height, sitting height, total leg length, trunk length, and total arm length were found shorter in endurance runners as compared to the average youngmen, and the differences were found to be statistically significant. (3) The circumferences of the endurance runners, i.e., neck, shoulder, abdomen, hip and knee, were also found to be smaller than those of the control group. (4) The bone diameters of hip, femur and ankle of the endurance runners were also shorter than those of the average youngmen but the shoulder diameter differences were not significant.
Cureton (1951) studied champion athletes and found that typical track men were slight in skeletal framework with a relatively longer upper leg ratio and trunk relationship. He also noted that most good sprinters had narrow hips, and that the more ponderous men with longer and larger trunks, but with relatively short limbs, were mostly successful in weight-lifting, wrestling, gymnastics and diving.

Mathew (1984) studied the relationship of selected anthropometric measurements (height, weight, arm length and upper body length) to performance on Brady volleyball test. Pearson's Product Moment Correlation (zero order) was employed to study the relationship of volleyball playing ability to each of the selected anthropometric measurements. For testing the hypothesis the level significance was set at .05. Based on the findings of the study the following conclusions were drawn: (1) The height and weight of the players contributed to a much greater extent to the performance of Brady volleyball test and to volleyball playing ability. (2) Arm length was also found to be an advantageous factor in the performance of Brady volleyball test. (3) Leg length and upper body length contributed to the performance on the said test to a very limited extent.
Baacke (1964) utilized data from 87 male students of high schools to determine the relationship of selected anthropometric and physical performance measures to performance in the running hop-step. He concluded that all the variables as measured in the study showed significant relationship with criterion beyond the .05 level of confidence.

Sraque (1975) studied the relationship of certain physical measurements with swimming speed in male swimmers. Several ways of examining the relationship of swimming speed to physical measurements were investigated for all competitive strokes. These were free style, back stroke, breast stroke and butterfly. The physical measurements were height, weight, sitting height, lower leg length, foot length, forearm length, waist girth, ankle girth, hip width, shoulder width, chest thickness, triceps skinfold, subscapular skinfold, shoulder flexion, ankle flexion, knee extension, elbow extension, vital capacity and centre of gravity. The stepwise method of multiple regression was used in all analysis. The most consistent physical measurements were foot length and biceps size. Each was found significant in at least one analysis for each of three strokes. In each case longer feet were associated with slower times and longer biceps were associated with faster times.
Espendchade (1963) studied the relationship between physical performance of school children and age, height and weight. The relationship of age, height and weight to performance of boys and girls on the California Physical Performance tests were studied in order to evaluate those factors as basis for the grouping of students and for the establishment of norms for test performance. Relationship of performance with height and weight were low. High correlations were obtained for boys of junior high school age in the jumping and throwing events. If grouping according to the size is desired, the California classification plan is superior. It shows that age has got a direct bearing on physical performance.

Cozens (1930) studied stature in relation to physical performance of college men. He concluded that (a) there was a negligible correlation between age and height; (b) negligible correlation between age and weight; (c) Age had no bearing upon performance in general athletic ability; (d) height and weight were apparently influencing factors to some extent in the matter of performance.

Cureton (1941) has stated that, in general, people with long legs and long arms, and with relatively short and small trunks, were physically weak types in
long-sustained heavy work, but they might show great speed and endurance at high levels of athletic activity. Long third class levers were noted for speed and range of action as well as for their efficiency for force.

Muthiah and Venkateswarlu (1973) studied the Indian track and field athletes and noticed that throwers were heavier, taller and older than other athletes. Among runners, the age increased and the height and weight decreased with the increase in the distances they ran. Jumpers and hurdlers were taller and heavier than sprinters, but were shorter and lighter than throwers. The decathletes were the second heaviest as they were all-rounders.

Sodhi (1980) studied the top ranking Indian National Basketballers and found that with the increasing standard of the participants the average height was greater. The top class teams in the world had a greater average height than teams of lower standard. A significant correlation was seen between height and performance in competitions. The value of correlation was very high with the field basketball scores. Thus, the greater the height of a basketballer, the better his performance.

Sidhu and Wdhan (1974) worked on footballers
who were found to be of average height with larger trunks and smaller lower extremities than the controls. They also had more of lean tissue in the extremities than the latter.

Hirata (1966) studied the size and age of the competitors of 1964 Olympic Games. Considerable differences were observed in age, height, and weight of participants in different events.

Tanner (1964) also studied track and field athletes at the Rome Olympics. His analysis was presented in terms of body size, length, girth, proportion and amount of tissues in limbs. There were outstanding differences among the means of different events.

Cureton (1951) studied the structure of 21 male swimmers who were members of the 1948 U.S.A. Olympics team, and also track and field champions. A considerable number of lengths, circumferences and diameters were taken. He indicated that structural differences could be related to the sports speciality.

Kohlraush (1929) reported on measurements made on approximately 300 athletes at the 1928 Olympic games in Amsterdam. Mean values were presented for track and field athletes, boxers, wrestlers, weight lifters,
waterpolo players etc. The data indicated that there were differences in body dimensions between various events. It was the first adequate data on the body size of Olympic athletes in different sports.

Carter et al. (1982) compared body size among athletes of the Montreal Olympics, 1976, athletes of the Mexico Olympics and some Canadian students. In terms of percentiles male and female athletes of the Montreal Olympics were larger than those of the Mexico Olympics on variables including length, breadth and girth but were smaller in shoulder breadth. The male athletes were older than the students but had narrower hips, whereas the female athletes were lighter than the students.

Metheny (1939) studied the differences between the Negro and White athletes in respect of their body measurements. The results indicated that superiority in certain sports might be attributed to those differences.

Tanner and his colleagues (1960) conducted a study of the anthropometric measurements of the Olympic athletes who participated in 1960 in the Rome Olympics. They studied athletes of different races but of the same events in an attempt to study their height, weight and other body measurements. They were compared with each race and the Whites were compared with the Negroes. It was found that Negroes were larger than the Whites in some measurements; their arms were longer than those
Sidhu et al. (1975) took the upper arm roentgenograms and some anthropometric measurements of 22 throwers and compared them with 45 normal non-athletes. The throwers were found to be significantly taller and heavier with bulkier builds of larger circumferential and skeletal measurements. Their lean body mass was greater than that of the controlled sample. Roentgenograms assessment displayed that the constant throwing exercise had resulted in greater development of the upper arm muscles, especially the triceps.

Miscellaneous

Ghai (1984) studied the relationship of selected physique characteristics and motor ability components to performance of gymnasts. Twenty male gymnasts who had participated in All India Inter-University Competition held at Amritsar (1983-84) were selected as subjects. The data on the dependent variable (gymnastic performance) and the independent variable of height, weight, chest girth, thigh girth, upper arm girth, strength, flexibility, agility, and dynamic balance were collected. Rank difference method of correlation was used to compute coefficient of correlations between gymnastic performance (dependent variable) and each independent variable of height, weight, chest girth, thigh girth, upper arm
girth, strength, flexibility, agility and dynamic balance. Analysis of data revealed that there was a significant relationship between gymnastic performance and total strength \( (r = .593 \text{ required to be significant at } .05 \text{ level was } .444 \text{ for } 28 \text{ degree of freedom}) \) and gymnastic performance and total flexibility \( (r = .566) \) and also between gymnastic performance and dynamic balance \( (r = .737) \), whereas in the case of other variables, i.e., height, weight, chest girth, upper arm girth and gymnastics performance did not seem to have significant relationship.

Sodhi and Singh (1989) conducted a study on the physique and performance of Indian gymnasts during the national coaching camp at National Institute of Sports, Patiala and the National Gymnastic Championship held in New Delhi during 1982. The data of 44 gymnasts was divided into two groups: those selected for the 9th Asian Games formed group A, and all the other formed group B. The gymnasts of each group were compared with a control sample \( (N=42) \), as well as the Olympian reported
elsewhere. Each subject was examined with anthropometric measurements and selected tests of performance. The latter consisted of dips on parallel bars, sit-ups, standing broad jump, trunk flexibility, and scores achieved through competitive performance. The typical characteristics of the physical structure of gymnasts were found to be a shorter stature, a lighter body weight, a better development thoracic cage, longer and stronger upper extremities, and lesser body fat. The Indian high performance gymnasts in group A were found to be stronger in sit-ups and standing broad jump than the poorer ones in group B. When compared with the Olympic gymnasts of 1968 and 1976, the Indian gymnasts were found to be similar in stature, body weight and endomorphic components of somatotyping. They were, however, significantly weaker in the development of the thoracic cage and upper extremities with a relatively poor strength development. They were also less developed in the bone component as indicated by the results of elbow and femur widths in relation to stature.

Basco (1973) reviewed the physical and physiological characteristics of champion male gymnasts and concluded that they have less superficial fat, a higher centre of
gravity, more strength, more flexibility, better balance, more agility, more explosive power, a faster reaction time, a lower heart-beat and lower blood pressure.

Johnson's (1968) study explored the relationship of balance, speed, strength, height, arm and leg length to success in collegiate wrestling. The subjects (N=208) for this investigation were collegiate wrestlers with at least 2 years varsity experience who had wrestled in at least 50% of their team's bouts during the 1976-77 school year. Subjects were classified as successful, average, and unsuccessful according to their win-lose percentages. A second classification was by weight (light weight, middle weight and heavy weight). All subjects were measured for arm and leg length and tested for RT, MT, static elbow flexion, strength, explosive leg strength, and dynamic balance. Treatment of the data by ANOVA showed no difference among the wrestlers in the 3 weight divisions on dynamic balance, explosive leg strength and RT. In elbow flexion strength the middle weights were stronger than the light weights. The light weights and middle weights were faster in Mt and RT than the heavy weights. The unsuccessful wrestlers had longer legs than the average and successful wrestlers. Analysis by multiple R and regression showed that no combination of the independent variables was useful in predicting success.
Schwarzkoff (1963) used Iowa-Brace Test as a measuring instrument for predicting gymnastic ability. The Iowa-Brace Test was administered to 33 students in a gymnastic skills class prior to a quarter of instruction. The Minnesota gymnastic skills test and gymnastic class final performance test were given following instruction. The correlations between the Iowa-Brace Test and the gymnastics skills tests were .529 and .646.

Giese (1981) tested 19 male all round gymnasts from the Big-Eight Conference and a control group of 21 male Kansas University students on 12 physiological parameters: the State Trait Anxiety Inventory and Lakies Test of Competition Attitudes. From the 40 subjects, four groups were formed according to their level of gymnastic placement of experience. The top nine gymnasts reflected by their placement in the 1978 Big-Eight conference meet served as group one. Ten other Big Eight all round gymnasts served as group two. The control group was divided into two groups according to experience in high school competition. ANOVA between the Big-Eight Gymnasts and the control group revealed that four of the 12 physiological parameters (Flexibility, Strength, Per cent fat and Balance with vision) were significant at .05 level. ANOVA across the four groups revealed three parameters
Flexibility, Strength and Per cent Fat) and showed significant differences between the four groups. Two methods of prediction were used in an attempt to classify the Gymnasts into elite or good groups. Step-wise parameters revealed that mean arterial blood pressure could better predict the gymnast’s actual all round score.

Voll (1979) investigated if ability in basic modern dance skills could be predicted by means of selected anthropometric and physical fitness measurements. Data for this study were collected on 24 female students participating in 1 of 3 North Eastern Pennsylvania colleges. Measurements of height, left tribiale height, upper leg length, flexibility, abdominal strength, leg strength, cardio-vascular fitness and somatotyping were taken. These measurements and 6 anthropometric ratios were statistically treated by DMDOZR stepwise regression programme developed by the Health Sciences computing facility, University of California at Los Angeles. A regression equation with a multiple R of .867 was presented by the author for the prediction of ability in basic modern dance skills and prediction tables for its computation of 5 anthropometric measurements and 2 physical fitness tests on the basis of the findings of this study. The author concluded that ability in basic
modern dance skills can be predicted from selected anthropometric and physical fitness measurements.

Bandyopadhyay (1982) found out the relationship of selected anthropometric measurements, physical fitness, and motor ability to soccer skill performance. All subjects were tested in selected anthropometric measurements which were chest girth, upper arm girth, thigh girth, calf girth height and weight. They were also tested in AAHPER Youth Fitness Test for estimating physical fitness, and Barrow's motor ability test for assessing motor ability, and McDonald soccer skill test for measuring soccer skill performance. The findings indicate that the McDonald skill performance has a high correlation with physical fitness and motor ability. The obtained value .86 and .89 respectively. These values of correlation were statistically found significant at .05 level of confidence. The results of the study seem to permit the following conclusions: (1) There was a high correlation in physical fitness level as obtained from AAHPER Youth Fitness Test with soccer skill performance; (2) soccer skill performance was highly correlated with motor ability as obtained from Barrow's Motor Ability Test of the soccer players; (3) among the selected anthropometric measurements only thigh girth had significant relationship with soccer skill performance of the soccer player; (4) the upper arm
girth, chest girth, calf girth, height and weight had no relationship with McDonald Soccer skill performance.

Sasunia (1982) studied the relationship between height, agility, flexibility, reaction time, vertical jump and sprinting speed of the soccer players. The findings of the study showed that there were no correlations of height with reaction time, vertical jump and speed. The study also revealed that there was a high correlation between flexibility and speed with the obtained value of correlation being .53, which was found statistically significant at .05 level of confidence. But flexibility had no relationship with vertical jump and reaction time as the obtained values were .18 and .34 which were not found statistically significant. Therefore it can be contended that while selecting soccer players, greater consideration should be given to agility and flexibility instead of considering height only.

Rydalch (1971) carried out a study to identify independent variables that were significantly related to football success and to formulate a regression equation to predict football success. Data was collected on 812 football players from 17 junior colleges located in 8 states. Head football coaches at the participating colleges rated their own individual players and the ratings of the coaches were analyzed by multiple correlation and
regression analysis at Brigham Young University. The findings of the study were: (1) The twelve independent variables which were analyzed were significantly related to football success at the .01 level. (2) Six factors honors, speed, weight, team record in high school, height and size of high school participants were selected as those variables with the highest relationship to success.

Sinha (1984) found out the relationship of selected motor traits and anthropometric variables to performance in AAHPER basketball skill test. To establish relationship between selected motor traits and anthropometric variables to performance in AAHPER basketball skill test, the coefficient of correlation "r" was used. On the basis of the findings of the study the following conclusions were drawn: (1) Explosive power, agility and cardiovascular endurance are the key motor traits that underlie performance of skills in Basketball. (2) Height as well as relative leg length measurements (crural index) are the main anthropometric characteristics which contribute to skills in Basketball. (3) The motor traits of speed, grip strength and flexibility are not the prime factors for performance of skills in basketball. (4) Excess body weight has restricting effect on basketball performance.

Bhole (1994) determined the relationship of absolute leg length, foot length, dynamic power, ankle flexibility
and agility to jumping ability in volleyball using the three stride rhythm. Twenty male volleyball players of the Lakshmi Bai National College of Physical Education, Gwalior, were selected as subjects. Product correlation was used to compute correlations between jumping ability and each of the selected independent variable i.e., absolute leg length, relative leg length, foot length, dynamic power, ankle flexibility and agility. For testing the hypothesis the level of significance was set at .05 level of confidence. The findings of the study indicated the foot length of the subjects was a very reliable variable for predicting jumping ability of male volleyball players, as the correlation value between foot length and jumping ability obtained was .726. The correlation value between dynamic power and jumping ability was .441. The correlation value between right as well as left foot ankle flexibility and jumping ability, and agility and jumping ability obtained were .415, .716 and .443 respectively. The value indicated low positive relationship which was found to be insignificant at .05 level of confidence. On the basis of the findings of the study the following conclusions were drawn: (1) Foot length and dynamic power showed significant relationship with jumping ability in volleyball using the three stride rhythm. (2) Right and left foot ankle flexibility also showed significant positive relationship to jumping ability. (3) Agility was significantly related to jumping ability.
of male volleyball players. (4) The variable of absolute leg length, fore leg length, and thigh length showed insignificant relationship to jumping ability.

A study was undertaken by Joseph (1983) to determine the relationship of power, agility, shoulder flexibility, arm and leg length to volleyball playing. Thirty male volleyball players of the Lakshmibai National College of Physical Education, Gwalior were selected as subjects. Power was measured by the Sargent Jump in centimetres, agility by 20 metre shuttle run in seconds, shoulder flexibility by graded stick in centimetres and arm length and leg length by calibrated steel tape in centimetres. Playing ability was based on the subjective judgement of three experts and the score was the average of the three judges’ ratings of each subject. Product moment correlation was used to compute correlation between playing ability and each of the selected independent variables. The findings indicate that power of the subject was a very reliable variable for predicting playing ability of male volleyball players, as the correlation value between power and playing ability obtained was .65. The correlation values between agility, shoulder flexibility, and playing ability obtained were -.08 for agility and .24 for shoulder flexibility. These two values were found insignificant at .05 level of confidence. From the findings of this study it may be concluded that: (1) Power
is the most reliable variable in prediction of playing ability of men volleyball players. (2) Arm length and leg length are also reliable variables in prediction of playing ability of male volleyball players. (3) The variables of agility and shoulder flexibility show insignificant relationship in prediction of playing ability of male volleyball players.

Bakker (1969) studied factors associated with success in volleyball. The subjects were 28 members of the women's extramural volleyball teams at Illinois State University. Two experienced volleyball coaches established the criterion by rating each player on her playing. The following variables were measured: height, weight, leg strength (extensor) using the multiple angle testing unit, grip strength using an adjustable dynamometer, skin folds using the lange caliper, jumping ability using the jump and reach test, and an apparatus constructed by the investigator to measure reaction and movement times. Through these tests for correlations it was found that jumping ability and reaching time were significantly related to success in volleyball. A multiple correlation (R) of .718 obtained between the nine variables and the criterion. An R of .53 was obtained between the criterion and reaction time plus jumping ability plus weight. The regression equation computed in this study could be used to predict
success in volleyball playing.

Murugesan (1981) established the relationship of
height, agility and vertical jump to spiking in volleyball.
Thirty male volleyball players of Lakshmi Bai National
College of Physical Education, Gwalior, were selected as
subjects. For estimating standing height, agility,
vertical jumping ability and spiking ability the following
tests were employed. Height measured against wall in
centimetres, 40 yards shuttle run in seconds, Sargent
jump in centimetres and spiking ability test with the
use of five point rating scale respectively. Zero-order
co-relation was used to compute correlation between
spiking and each selected variable i.e. height, agility
and vertical jump. The findings indicate that the
vertical jump is a very reliable variable for predicting
spiking ability of male volleyball players. The order
of merit was a combination of three variables, i.e.,
height, agility and vertical jump. The value of multiple
correlation obtained was .65 and it was proved to be the
most reliable combination because the value of multiple
correlation .65 obtained was maximum. Therefore, this is
the best combination which can be used for predicting
spiking ability of male volleyball players.

Shondell (1975) established the relationship of
selected motor performance and anthropometric traits to
successful volleyball players. He used a six item battery for this purpose. He found out that power appeared to be the most significant factor in successful volleyball performance.

Promoda Devi (1934) studied the relationship of selected physical variables such as strength (Arm strength, Leg strength), agility, speed, flexibility, anthropometric measurements, weight, height, arm length, leg length, foreleg length, thigh length, ponderal index, crural index to performance in shot put. Product moment correlation method was used to compute correlation. The findings of the study revealed that there was a significant correlation between the arm strength and shot put performance \((r = 0.452)\); leg strength and shot put performance \((r = 0.419)\); speed and shot put performance \((r = 0.428)\), and flexibility and shot put performance \((r = 0.512)\). But there was no significant correlation between weight, height, arm length, leg length, foreleg length, thigh length, ponderal index, crural index and shot put performance.
Murlidharan (1984) found out the relationship between anthropometric and physical performance variable measures to performance in long jump. The average age of the subjects was 22 years. Product Moment Method was used to compute correlations between performance in long jump to each independent variable namely, standing broad jump, 50 yard dash, shuttle run (4 x 10 yards), sit and reach, vertical jump, leg length, height and weight. The data was tabulated in the form of scatter grams. The independent variables were taken on 'X' axis and the dependent variables on 'Y' axis. For testing the hypotheses the level of significance was set at .05 level of confidence. The findings indicated that the anthropometric and physical performance variables have significant relationship with performance in long jump. From the findings of the study it may be concluded that: (1) Leg length, height, standing broad jump, 50 yard dash, shuttle run (4 x 10 yard) sit and reach and vertical jump were the most significant independent measurements in prediction sources in running long jump. (2) Body weight did not prove to be reliable when single independent variable was correlated with the performance of running long jump. Therefore, weight should not be used singly for predicting performance in running long jump.
ceterson (1962) predicted basketball performance using psychomotor, cognitive and anthropometric measures. A total of 43 female members of the top four teams in the 1962 Missouri Small College Basketball Tournament served as subjects. The contribution of GPA, anaerobic leg power, 15 yard dash, 30 yard dash, total body RT, TWT, height and weight to basketball performance were determined. Basketball performance was determined by a specially designated formula by R.K. Kay Ht. (r = .388) was the only significant (P<.05) predictor. The 15 yard dash, total body TWT, and power were next. The R for the four top variables was .56 (P<.01).

Hindmarch (1960) administered the following tests to 100 Canadian born white boys: anthropometric, height, weight, height-weight ratio, arm length, sitting height and leg length, performance in one minute sit ups, standing broad jump and one minute squat thrusts; trunk flexibility criteria-Leighton trunk and hip extension-Flexion test, Cureton Trunk Flexion Test, modified Scott French Babing Test and Kraus-Weber Flexion Test. The correlation between the anthropometric and performance tests and the flexibility criteria were low; the highest was .36 between the standing broad jump and the Scott French Test. The Kraus-Weber Test correlated .687 with the Scott-French Test .630 with the Cureton Test and .779 with Leighton's test.
Edmund and Brush (1979) carried out a study on physiological and anthropometric assessment of successful teenage female distance runners. Physiological and anthropometric measures were taken in a group of young women, mean age = 16.2 years, who had been training regularly by running approximately 50 miles per week for 2 years. Their mean VO$_2$ max of 63.24 ml/kg min is among the highest ever recorded in a group of young women. Anthropometric measures included selected segment lengths, diameters, skinfolds and circumferences. These young women appear to be of average height, low in body weight and subcutaneous body fat have a high component of ectomorphy and a smaller overall skeletal framework than non athletes.

Bowmen (1971) investigated the relationship between twenty-nine biographical, physiological and psychological factors and success in wrestling. The purpose of this study was to identify independent variables that were significantly related to wrestling success and to formulate a regression equation to predict wrestling success. One hundred thirty six Idaho high school wrestlers were tested during the 1969-70 wrestling season. The data from the factor tests and the season's win-lose records were analyzed by multiple correlation and regression analysis at Brigham Young University. The findings of
the study were: (1) All twenty nine independent variables, the biographical variables and the physiological variables were significantly related to wrestling success at the .05 level. (2) Seven factors — age, years of wrestling experience, hand grip strength, upper body strength, cardiovascular endurance, desire to achieve and desire to experiment — were significantly related to wrestling success at the .05 level.

Characteristics of physique, motor and cardiovascular fitness were reported by Selder (1965) for 14 university ice hockey players, some of whom represented Canada in the 1964 winter Olympics. Most of the players were dominant mesomorphs with low adipose measurement. The majority were above average in dips and in dynamometrical strength but average or below average in other tests of motor fitness. Cardio-vascular test results were rated good to excellent. The test scores reflected the specific nature of hockey training done entirely on ice.

Lenback and Meconville (1966) reported low correlation between flexibility and anthropometric measurements, and between Somato type and flexibility. A high negative relationship was obtained between body fat and flexibility. Somato type components were found to correlate highly with anthropometric measurements employed in the study. Later on the same author reported
many significant correlations between strength and anthropometric measurements. The only somato type components were found to correlate significantly with muscle strength and mesomorphy.

Wolfe' (1980) investigated if the selected variables of lean body weight, physical work capacity and sport competition anxiety test was related to the successful performance of cross-country skiers in competitive racing. A total of seventy five volunteer subjects were included in the study. Pre-assessment tests to determine lean body weight, physical work capacity and sport competition anxiety level were administered to the subjects prior to the ski training and ski-races. These variables were combined with the demographic variables of age, height and weight to form six independent variables which were compared with the dependent variable statistically using 't' tests, inter-correlation matrix and multiple regression analyses. The 't' ratios revealed statistically significant differences at the .05 level between the means of the six independent variables for the groups of subjects, indicating that they were not representative samples of the same population and, therefore, were treated separately. (1) No substantial significant correlations were found between the independent variables and ski race time. (2) Negative relationships were revealed between physical work capacity and ski race time.
No relationships were found between the sport competition Anxiety Test results and ski races time. (4) Relationships were found between combinations of two or more variables and ski race time. (5) Significant relationships were found for regression equations that predict ski race time in three groups studied. All significant correlations reported were considered positive, unless noted as negative relationships.

Mishra (1983) conducted a study to find out the relationship, if any, of selected physical and physiological variables to perform in fifty metre front crawl swimming. Data on the different variables was collected by administering tests adopting standard procedures. Arm strength was computed with the help of formula given in Roger's physical fitness index, ankles flexibility with the help of goniometer, vital capacity, with the help of spirometer, and body surface area with the help of "Du Dios" surface area formula. Within the limitations identified and on the basis of the results of the study the following conclusions were drawn: (1) There was significant positive correlation between arm strength, ankle flexibility and vital capacity to swimming speed. (2) There was no significant relationship between body surface area and swimming speed.

Wettstone (1938) conducted a study of the tests for predicting potential ability in gymnastics and tumbling.
A list of qualities which was thought that a good gymnast would possess was complied and sent to twenty-five of the country's outstanding coaches and gymnasts. Tests for 15 of the highest ranking qualities were obtained (interest, determination, physical courage, coordination, strength, kinesthetic sense, condition of heart, quickness of movement, precision of movements, flexibility, timing maturity, motor rhythms, educability and sensory rhythms). The subjects were a selected group of 22 gymnasts actively engaged in gymnastics at the University of Iowa. Eleven anthropometric measurements were taken. A test was constructed consisting of 3 elements. Thigh circumference, strength test (consisting of chinning, dipping and thigh flexion), Height and the Burpee test which predicted potential ability in gymnastics with multiple correlation of .79 by means of regression equation:

\[ X_a = -0.355 X_1 + 0.260 X_2 + 0.035 X_3 + 13.990 \]

A regression equation for \( r \) 0.12 which had a multiple correlation of .75 were also computed.

\[ X = -0.472 X_1 + 0.28 X_2 + 19.163 \]

Trussell (1965) carried out a study on prediction of success in a motor skill on the basis of early learning.
achievement. Forty college women learned a ball juggling
task during 27 practice periods (totalling 2,025 trials)
spaced over 9 weeks. Learning scores (gains) were found
moderately reliable ($r = .80$). They were not significantly
related to initial scores. However, appreciable correlat­
ions ranging from .32 to .59 were found between the
criterion (performance score on the 27th day) and
cumulated learning scores. Prediction of the criterion
by multiple correlations employing initial score and the
cumulated learning score through the 4th, 6th, 7th, 15th
and 19th practice day ranged from $R = .76$ to $R = .96$.
A two component exponential equation was effective
in describing the form of the learning curve.

Phipp's (1982) study was to compare selected general
ability tests, specific skill tests, and personality
traits as predictors of volleyball performances in high
school girls. 120 high school girls trying out for varsity
teams in six schools. The coaches of each team assigned
a subjective pre and post season score for each player.
The data from three schools were used to develop prediction
equations using a general linear model procedure. The
specific test model had the highest correlation with overall
performance. The combined equation of general and specific
had the highest relationship of any combined model to the
criterion score. The specific model was the most valid predictor of criterion scores followed by the combined general and specific model. There is little relationship between selected tests of general physical ability and volleyball performance. There is substantial relationship between selected specific skill tests and volleyball performance. The specific test model is the best predictor of volleyball performance. The specific test model and combinations of the general ability and personality with the specific are better predictor of volleyball performance than the coaches beginning of season judgement.

Moffatt et al. (1984) compared the body composition, physical dimensions and maximal physiological responses of 13 female high school elite gymnasts to 13 randomly selected nor-athletic high school females. Data was collected on age, height (Stadiometer), body fat Lange caliper from six sites, lean body weight (determined by differences), body density (hydrostatic weighing), VO₂ max (treadmill) and anaerobic capacity (bicycle ergometer). Data was analysed through 't' tests, multivariate analysis of variance and univariate P-tests were used to determine fat-folds individuals differences. Analysis of variance for repeated measures was utilized to determine the effect of time on anaerobic power. It was concluded that female high school gymnasts had
similar skeletal structure when compared to non-athletic controls. Non-athletic high school females had less tissue fat and more body fat as indicated by densitometry and anthropometry. The per cent body fat of these gymnasts was 14-22 per cent less than that reported for more mature female gymnasts. The female gymnasts also exhibited higher $V_{O_2 \max}$ and performed better on tests to estimate anaerobic capacity and anaerobic power output than controls.

Blackington (1966) investigated the value of height weight classification plan as a predictor of the motor ability of college women. A 3 x 3 height weight classification plan was developed from heights and weights of 1732 women at Idaho State University from 1959 to 1963 using the top 25, middle 50 and bottom 25 per cent on each axis. The Scott Motor Ability Test was administered to 322 women at Idaho State University grouped according to this plan during the fall semester of 1963-64. Significance of mean differences was tested for the 4 tests and the total battery. The tall group was significantly superior to the medium and short
groups in total motor ability but the differences between weight groups were not significant. The tall-slender group was significantly superior to the short slender, short heavy and medium-heavy were consistently lowest in motor ability but no group was significantly superior on all of the test items. Separate achievement scales for the 9 groups seemed unwarranted.

Summary

After reviewing critically literature related to motor fitness components, anthropometric measurements and performance in gymnastics, it has been found that scholarly attempts have been made separately to investigate the relationship of motor fitness components and anthropometric measurements to performance in gymnastics. On the basis of studies on motor fitness components and performance in gymnastics it could be concluded that, beside other components, flexibility and strength are primary prerequisites both qualitatively and quantitatively for good execution of the various movements. Obviously these abilities are of very great importance in gymnastics because of the nature of the sport.

Studies on anthropometric measurements in gymnastics are either of status type, or of comparative
nature, and correlational studies are contrary to each other in some instances. But there is general agreement among the researchers on the subject that a small and light body size and relatively greater strength in the upper body form an ideal structure for gymnasts.

It has been observed that no attempt so far has been made to investigate the relationship of motor fitness components and anthropometric measurements and performance in gymnastics at different levels of competition. Some studies that were carried out were at only one level of performance and not at different levels. The present investigator has made an attempt in this multi level direction and the value of his research lies in this.