Chapter II

REVIEW OF RELATED LITERATURE

The literature related to the problem has been presented in this chapter. Review of literature has been confined to the website of www.pubmed.com.

The literature related to any problem helps the scholar to discover what is already known, which would enable the investigator to have a deep insight, clear perspective and a better understanding of the chosen problem and various factors connected with the study. So a number of books, journals, and websites were referred. In the following pages, an attempt has been made to present briefly a few of the important researches and studies conducted abroad and in India, as they have significant bearing on the present study.

The reviews of the literature have been classified under the following headings.

1. Studies on Basketball
2. Studies related to Physical Characteristics
3. Studies related to Physical and Physiological Characteristics
4. Studies related to Physical and Anthropometric Characteristics
5. Studies related to Physical and Performance related Characteristics
6. Studies related to Physiological Characteristics
7. Studies related to Physiological and Anthropometrical Characteristics

8. Studies related to Physiological and Performance related Characteristics

9. Studies related to Anthropometrical and Performance related Characteristics

**Studies on Basketball**

*Mehmet Pense, Behic Serpek (2010)* researched the physical and biomotor features of female students who are in puberty and play basketball. Also, it’s been aimed to test whether the Eurofit battery which is used to determine physiological and biomotor features can be used in the elimination of talented basketball players. Anthropometric measurement (height, weight, percentage of body fat) and physiological - biomotoric measurements (flamingo balance test, test of disk touching, sit and reach flexibility test, long jump while standing still, 30 sec sit-up test, bent arm pull-up test and 10x5m push up run) were performed by Eurofit test battery. The research was applied in the province of Konya with 51 female students. 30 of them were playing basketball (age: 14.93±0.86) and 21 (age: 15.00±0.83) of them had no physiological activity at all. These applied Eurofit tests on basketball players allows them to get longer body length, stay more in balance, to have greater distance of flexibility, be further distance of standing long jump, to have a higher claw force, having more numbers on doing crunches and it’s been mentioned that 10x5 the running test doing crunches are faster than usual and these differences are found Statistically significant (p<0.05). It’s been determined that there weren’t any significant changes between the groups that are playing basketball and aren’t playing in the arm and shoulder
forces with their body weights, body fat percentage, duration of touching disks and bent arm pull-up (p>0.05). As a conclusion, it is determined that the physiological and biometric values of female basketball playing students are higher than the same aged students with no activity. On the other hand, it’s been also determined that because of the appropriate content of the test, Eurofit test battery can help to choose the talents of the basketball.

Ersan Kara, Talat Bayburluoglu, Serdar Ceyhun (2010), In this study, STAI (State-Trait Anxiety Inventory) was applied to 92 sportsman who were playing at several university basketball teams, 31 sportsman were female and 61 sportsman were male, Sportsman who were attended the study were evaluated in terms of age, gender, length, weight, cigarette and alcohol usage; and trait anxiety levels were measured separately for each group and whole group, anxiety levels were tested statistically according to genders and results taken at competition. There was no suggestive statistical difference at female, male and whole group for and trait anxiety scores between groups which were successful and unsuccessful at the end of the competition. But when a matching was done according to genders; anxiety scores were confirmed as 38.65 + 7.3 and trait anxiety scores were confirmed as 42.36 + 7.09 at female sportsman, these values were by order of 32.57 + 12 and 37.35 + 10.38 at male sportsman. In matching these values by using t-test; it was confirmed that there was a statistically meaningful difference (p< .05). This situation indicated that gender factor may be impressive on and trait anxiety.
Robert J. Sonstroem, Pasquale Bernardo (2008) studied the extension of the inverted-U curve hypothesis was tested by defining low, moderate, and high arousal levels as an athlete’s lowest, median, and highest pregame state anxiety values across three games of a basketball tournament. Basketball performance was measured by a game statistics composite (PERF) and by total points (TP) in each game. Subjects were 30 female university varsity basketball starters from six teams. They were trichotomized on competitive trait anxiety (A-trait), and a 3´3 ANOVA with repeated measures on A-state categories was employed. Significant A-state effects (p < .01) were found for both dependent variables: composite game performance (PERF) and total points (TP). Although A-trait predicted absolute A-state levels extremely well (p < .001), it failed to achieve a significant relationship with performance. When intrasubject T-scores for PERF and TP were regressed separately on intrasubject A-state T-scores, the relationship of variables was seen to consist essentially of a quadratic function which explained 18.4% and 16.9% of within-subject variance for PERF and TP, respectively. High A-state scores were associated with poorest performances in all three trait groups, but plotting performance T-scores across A-state categories indicated this effect to be particularly pronounced in high competitive trait-anxiety subjects.

McKenzie Gillam (1985) tested thirteen college basketball players, within two weeks after their last competitive game, were compared with 14 physical education majors not involved in varsity sports for purposes of identifying those physical and anthropometric qualities necessary for participating in college basketball. Three anthropometric characteristics were found as significantly contributing to participation. Basketball players were 10.53 cm taller and heavier
in terms of lean body weight (9.39 kg.) than the nonparticipants. No differences were found between total body weight, percent body fat, and fat weight of the two groups. The basketball players were found to have a lower endomorphy (3.33) value. No other body type differences were identified from Health-Carter somatotype evaluations. Physical qualities contributing to basketball ability were also identified. The collegiate athletes were found to be superior to the nonathletes in terms of both acceleration and maximum speed and agility. The power of basketball players (154.12 kg-m/sec.) exceeded that of nonplayers (135.20 kg-m/sec.). General muscular endurance of the players was 35% greater than the nonplayers. Isotonic measures of upper and lower extremity muscular strength did not differ significantly between the two groups. No significant difference in predicted maximum oxygen consumption was found between the basketball players (46.4 ml/kg.min.) and the nonparticipants (42.7 ml/kg.min.). Flexibility of the lower back and posterior thigh was also not found to be a factor contributing to basketball participation. Application of these findings could prove most useful in the recruitment of basketball personnel and in the establishment of training programs to optimize playing ability.

Allen F. Anderson et al., (2001) performed a prospective study based on the hypothesis that physiologic differences exist between men and women in strength after adjustments for body weight; that the size of the anterior cruciate ligament is proportionate to the strength of its antagonists, the quadriceps muscles; and that women have a relatively small anterior cruciate ligament, thus predisposing them to a disproportionate number of anterior cruciate ligament injuries. One hundred matched high school basketball players, 50 male and 50
female, were evaluated with anthropometric measurements, body fat analysis, muscle strength evaluation, and magnetic resonance imaging measurements of the intercondylar notch and cross-sectional area of the anterior cruciate ligament at the outlet. The male players were taller and heavier than their female counterparts, although they had 11% less body fat. Male players had statistically greater quadriceps and hamstring muscle strength than female players, even when adjustments were made for body weight. With adjustments for body weight, the size of the anterior cruciate ligament in girls was found to be statistically smaller than in boys. There was no statistically significant difference in the notch width index between the sexes. The study data support our hypothesis that sex differences in anterior cruciate ligament tear rates are caused primarily by several interrelated intrinsic factors. Most importantly, stiffness and muscular strength increase stress on the anterior cruciate ligament in female athletes. The anterior cruciate ligament, when adjustments have been made for body weight, is smaller in female athletes, and therefore, probably does not compensate for the lack of stiffness and strength.

Joseph J. Greene, et al., (1998) determined possible anthropometric and performance sex differences in a population of high school basketball players. Measurements were collected during the first week of basketball practice before the 1995-1996 season. Varsity basketball players from 4 high schools were tested on a battery of measures chosen to detect possible anthropometric and performance sex differences. Fifty-four female and sixty-one male subjects, from varsity basketball teams at high schools enrolled in the athletic training outreach program at the University of Wisconsin Hospital Sports Medicine Center in
Madison, WI, volunteered to take part in this study. We took anthropometric measurements on each of the 115 subjects. These included height, weight, body composition, ankle range of motion, and medial longitudinal arch type in weightbearing. Performance measures included the vertical jump, 22.86-m (25-yd) shuttle run, 18.29-m (20-yd) sprint, and single-limb balance time. We found significant anthropometric and performance sex differences in a cohort of high school basketball players. Further study of these measures is necessary to determine if these differences can predict the risk for ankle injuries in this particular population.

Yener Bekta et al., (2007) aimed to analyse the somatotype and body composition characteristics of female basketball players and to demonstrate the changes between different category levels. For this purpose 37 female basketball players were subjected from Et-Balik Sports Club representing 4 different categories. 11 anthropometric measurements; body weight, height, humerus and femur bicondylar breadth, biceps, triceps, subscapular, suprailiac and thigh skinfold thickness, biceps and thigh circumference data were collected according to the International Biological Programme (IBP) and International Society for the Advancement of Kinanthropometry (ISAK). The mean age of the subjects were 13.84 ± 4.34 (year) where weight 55.4 ± 15.7 (kg) and height 162.2 ± 11.6 (cm). Study results showed gradual increase tendency in body fat pattern through categories. Subsequently body somatotypes were differed between categories as well. As a general tendency the somatotype characteristics of the subjects were found to be endomorphic mesomorph.
Studies related to Physical Characteristics

Sleivert and Taingahue (2004) investigated the relationship between sprint start performance (5-m time) and strength and power variables. Thirty male athletes [height: 183.8 (6.8) cm, and mass: 90.6 (9.3) kg; mean (SD)] each completed six 10-m sprints from a standing start. Sprint times were recorded using a tethered running system and the force-time characteristics of the first ground contact were recorded using a recessed force plate. It was concluded that, concentric force development is critical to sprint start performance and accordingly maximal concentric jump power is related to sprint acceleration.

Wisløff, Castagna, Helgerud, Jones and Hoff (2004) determined whether maximal strength correlates with sprint and vertical jump height in elite male soccer players. Seventeen international male soccer players (mean (SD) age 25.8 (2.9) years, height 177.3 (4.1) cm, weight 76.5 (7.6) kg, and maximal oxygen uptake 65.7 (4.3) ml/kg/min) were tested for maximal strength in half squats and sprinting ability (0-30 m and 10 m shuttle run sprint) and vertical jumping height. It was concluded that, maximal strength in half squats determines sprint performance and jumping height in high level soccer players. High squat strength did not imply reduced maximal oxygen consumption.

Gissis et al., (2006) compared maximal isometric force, force-time curve characteristics, pedaling rate, vertical jump, and sprint performance among young soccer players from different competition levels. Fifty-four (54) young soccer players were divided into three groups according to competition level: the elite group (n=18) consisted of soccer players from the national youth soccer team of
Greece, the subelite group (n=18) consisted of youth soccer players who participated in the local championship, and the recreational group (n=18) consisted of recreational soccer players. All groups were evaluated for maximal isometric force, explosive force at 100 m/sec, peak force relative to body mass, rate of force development, squat and drop jump heights, 10 m sprint time, and pedaling rate. The findings of the present study suggest that the elite young soccer players can be distinguished from subelite and recreational young soccer players in strength and speed characteristics.

Lehance, Binet, Bury and Croisier (2008) compared pre-season muscular strength and power profiles in professional and junior elite soccer players throughout the developmental years of 15-21. One original aspect of our study was that isokinetic data were considered alongside the past history of injury in these players. Fifty-seven elite and junior elite male soccer players were assigned to three groups: PRO, n=19; U-21, n=20 and U-17, n=18. Functional performance was evaluated throughout a squat jump and 10 m sprint. New trends in rational training could focus more on the risk of imbalance and implement antagonist strengthening aimed at injury prevention. Such an intervention would benefit not only athletes recovering from injury, but also uninjured players.

Ronnestad, Kvasme, Sunde and Raastad (2008) compared the effects of combined strength and plyometric training with strength training alone on power-related measurements in professional soccer players. Subjects in the intervention team were randomly divided into 2 groups. Group ST (n = 6) performed heavy strength training twice a week for 7 weeks in addition to 6 to 8
soccer sessions a week. Group ST+P (n = 8) performed a plyometric training program in addition to the same training as the ST group. The control group (n = 7) performed 6 to 8 soccer sessions a week. The results suggest that there are no significant performance-enhancing effects of combining strength and plyometric training in professional soccer players concurrently performing 6 to 8 soccer sessions a week compared to strength training alone. However, heavy strength training leads to significant gains in strength and power-related measurements in professional soccer players.

Rousanoglou, Georgiadis and Boudolos (2008) determined the relationships between muscular strength and vertical jumping performance were examined in young women (14-19 years) track and field jumpers (n = 20) and volleyball players (n = 21). Results indicate the dissimilarity in the relationships between the knee extensor muscular strength and jumping performance in the young female track and field jumpers and volleyball players.

Smirniotou et al., (2008) determined the relationship between strength-power parameters and sprint performance and to predict sprint times from strength-power parameters. Twenty-five male young sprinters participated in this study. Squat Jump(SJ), counter-movement jump (CMJ), drop jump height (DJH), repeated jump(RJ) and 100m sprint time from block start, including reaction time (RT) and times at 10m, 30m and 60m were measured. Reactive strength index (RSI), the difference between counter-movement and squat jump (CMJ-SJ) and the mean velocities of the intermediate sections 0-10m, 10-30m, 30-60m, 60-100m (V0-10, V10-30, V30-60 and V60-100) were also calculated. In conclusion,
performance at 100m sprint is strongly associated with strength-power parameters. The best predictor of the overall performance is probably SJ (or CMJ).

**Vescovi and McGuigan (2008)** assessed the relationships between various field tests in female athletes. Altogether, 83 high school soccer, 51 college soccer, and 79 college lacrosse athletes completed tests for linear sprinting, countermovement jump, and agility in a single session. Linear sprints and agility tests (Illinois and pro-agility) were evaluated using infrared timing gates, while countermovement jump height was assessed using an electronic timing mat. Pearson's product-moment correlation coefficients (r) were used to determine the strength and directionality of the relationship between tests and coefficients of determination (r²) were used to examine the amount of explained variance between tests. The results of this study indicate that linear sprinting, agility, and vertical jumping are independent locomotor skills and suggest a variety of tests ought to be included in an assessment protocol for high school and college female athletes.

**Chaouachi et al., (2009)** examined the relationship between squat 1 repetition maximum (1RM) and basketball-relevant tests and the variables that influence agility (T-test) in elite male professional basketball players. In light of the present study's findings, agility should be regarded as a per se physiological ability for elite basketball players. Consequently, basketball-specific agility drills should be stressed in elite basketball training. Given the association between squat 1RM performance and short sprint times, squat exercises should be a major component of basketball conditioning.
Halet, Mayhew, Murphy and Fanthorpe (2009) determined the relationships among pull-ups, lat-pull repetitions, and 1 repetition maximum (1RM) lat-pull in elite women swimmers and to assess the effect of various anthropometric dimensions on each exercise. Women members (n = 28) of an elite National Collegiate Athletic Association (NCAA) Division II swim team were measured for their ability to perform a maximum number of free-hanging pull-ups, 1RM lat-pull, and lat-pull repetitions at 80% of 1RM. Anthropometric dimensions included selected arm lengths, percent body fat (%fat), and lean body mass (LBM) estimated from skinfold measurements. These results confirmed that the seemingly analogous exercises of pull-ups and lat-pulls were not highly related and should not be substituted for one another in a training regimen.

Harrison and Bourke (2009) investigated whether an RS training intervention would enhance the running speed and dynamic strength measures in male rugby players. Fifteen male rugby players aged 20.5 (+/- 2.8) years who were proficient in resisted sledge training took part in the study. The subjects were randomly assigned to control or RS groups. The RS group performed two sessions per week of RS training for 6 weeks, and the control group did no RS training. Pre- and postintervention tests were carried out for 30-m sprint, drop, squat, and rebound jumps on a force sledge system. The results suggest that it may be beneficial to employ an RS training intervention with the aim of increasing initial acceleration from a static start for sprinting.

Requena et al., (2009) determined muscle strength and power output characteristics in a group of professional soccer players and to identify their
relationships with 2 functional performance tests (vertical jumping height and 15-m sprint time). Maximal strength and power indices attained against different loads in barbell back squat exercise, isometric maximal force of the knee extensor and plantar flexor muscles, isokinetic peak torque of the knee extensors muscles, vertical jumping height in squat and counter-movement jumps, and 15-m sprint time tests were assessed in 21 semiprofessional soccer players (age 20 +/- 3.8 years). It was concluded that in semiprofessional soccer players (a) isometric and isokinetic muscle strength assessed in an open kinetic chain were not movement-specific enough to predict performance during a more complex movement, such as jump or sprint and (b) concentric half-squat exercise was principally related with the functional tests selected when it was performed against external loading within the range of the load in case of which the maximal power output was attained.

**Nesser, Huxel, Tincher and Okada (2010)** identified the relationships between core stability and various strength and power variables in strength and power athletes. National Collegiate Athletic Association Division I football players completed strength and performance testing before off-season conditioning. Subjects were tested on three strength variables, four performance variables, and core stability. The results of this study suggest that core stability is moderately related to strength and performance. Thus, increases in core strength are not going to contribute significantly to strength and power and should not be the focus of strength and conditioning.

**Comfort, Graham-Smith, Matthews and Bamber (2011)** determined the strength and power characteristics of forwards and backs in a squad of elite
English rugby league players and compare these findings to previously published literature from Australia. Participants were elite English rugby league players who were all regular first team players for an English Superleague club. Testing included 5-, 10-, 20-m sprint times, agility, vertical jump, 40-kg squat jump, isometric squat, concentric and eccentric isokinetic knee flexion and extension. Independent t-tests were performed to compare results between forwards and backs, with paired samples t-tests used to compare bilateral differences from isokinetic assessments and agility tests. The results demonstrate that absolute strength and power measures are generally higher in forwards compared to in backs; however, when body mass is taken into account and relative measures compared, the backs outperform the forwards.

Cortis et al., (2011) aimed to verify whether basketball players are able to maintain strength (handgrip), jump (countermovement jump [CMJ]), sprint (10 m and 10 m bouncing the ball [10 mBB]), and interlimb coordination (i.e., synchronized hand and foot flexions and extensions at 80, 120, and 180 bpm) performances at the end of their game. Ten young (age 15.7 ± 0.2 years) male basketball players volunteered for this study. During the friendly game, heart rate (HR), rate of perceived exertion (RPE), and rate of muscle pain (RMP) were assessed to evaluate the exercise intensity. These findings indicate that the heavy load of the game exerts beneficial effects on the efficiency of executive and attentive control functions involved in complex motor behaviors.
**Studies related to Physical and Physiological Characteristics**

*Davis and Brewer (1993)* suggested that the demands of the game for women are similar to those placed on male players. Women are reported to cover a similar distance (mean 8471m) to their male counterparts during a game and much the same proportions of the game appear to be devoted to exercise of varying intensities. Furthermore, female and male players appear to tax the aerobic and anaerobic energy systems to a similar level. The physical and physiological characteristics of female soccer players are comparable with those of other female games players and are more favourable than average for the population. It was concluded that, mean body fat percentages of between 19.7 and 22.0% and \( \dot{V}_{O_2} \text{max} \) values of between 47.1 and 57.6 ml/kg/min have been reported for elite female players, while faster than average sprint times are also characteristic of them.

*Tumilty (1993)* compared top teams and players with less able participants indicates that the components of anaerobic fitness-speed, power, strength and the capacity of the lactic acid system may differentiate better between the 2 groups. Generally, there is a reduction in the level of activity in the second half of games compared with the first. There is some evidence that increased aerobic fitness may help counteract this. Progressively lower muscle glycogen stores are one likely cause of reduction in activity, and nutrition also appears to be a key factor in minimizing performance deterioration, both in terms of overall diet and, more particularly, the ingestion of carbohydrates immediately before, during and after a game. There are evolutionary trends in the sport such as greater frequency of
games, changes in the roles of players, and new strategies and tactics which are placing increasing demands on the all-round fitness of players.

Deutsch, Maw, Jenkins and Reaburn (1998) determined physiological and kinematic data were collected from elite under-19 rugby union players to provide a greater understanding of the physical demands of rugby union. Heart rate, blood lactate and time-motion analysis data were collected from 24 players during six competitive premiership fixtures. Six players were chosen at random from each of four groups: props and locks, back row forwards, inside backs, outside backs. Heart rate records were classified based on percent time spent in four zones (>95%, 85-95%, 75-84%, <75% HRmax). Blood lactate concentration was measured periodically throughout each match, with movements being classified as standing, walking, jogging, cruising, sprinting, utility, rucking/mauling and scrummaging. A mean blood lactate concentration of 4.8-7.2 mmol x l(-1) indicated a need for 'lactate tolerance' training to improve hydrogen ion buffering and facilitate removal following high-intensity efforts. Furthermore, the large distances (4.2-5.6 km) covered during, and intermittent nature of, match-play indicated a need for sound aerobic conditioning in all groups (particularly backs) to minimize fatigue and facilitate recovery between high-intensity efforts.

Aziz and Chia (2000) examined the relationship between maximal oxygen uptake and repeated sprint performance in field hockey and soccer players. Experimental design: a descriptive study on the aerobic-anaerobic performance of intermittent team game players. The study was conducted at the Sports Medicine and Research Centre. Participants: forty male national team game players (22.6+-
4.2 years; 1.73+/−0.07 m and 63.7+/−6.2 kg) were involved in the study. Measures: all subjects completed a treadmill run test to exhaustion to determine maximal oxygen uptake and 8x40 m sprints either on the field or running track to determine repeated sprint ability performance. In Conclusion, maximal oxygen uptake was not correlated with the fastest 40 m sprint time but was moderately correlated with total sprint time. Since the shared variance between maximal oxygen uptake and total sprint time was only 12%, improving aerobic fitness further will only be expected to contribute marginally to improving repeated sprint performance of the team game players. It remains possible that a high level of aerobic fitness enhances other aspects of match play in games like soccer and hockey.

Gabbett (2002) investigated the physiological characteristics of subelite junior and senior rugby league players and establish performance standards for these athletes. A total of 159 junior (under 16, 15, 14, and 13, n = 88) and senior (first grade, second grade, and under 19, n = 71) rugby league players (forwards, n = 80, backs, n = 79), competing at a subelite level, underwent measurements of body mass, muscular power (vertical jump), speed (10 m, 20 m, and 40 m sprint), agility (Illinois agility run), and estimated maximal aerobic power (multistage fitness test). Data were also collected on match and training frequency and playing experience. The results show that there is a progressive improvement in the physiological capacities of rugby league players as the playing level increases.

Sallet, Perrier, Ferret, Vitelli and Baverel (2005) evaluated the physical and physiological characteristics of different first (ProA) and second division (ProB) professional basketball players, and to relate them to playing position and
level of play. A total of 58 players were divided into ProA and ProB groups and were assessed for physical characteristics, maximal treadmill test and a 30 s all-out test. The sample included 22 centers, 22 forwards and 14 guards. It was concluded that, many physical differences, most notably size, exist between players as a function of their playing position. But these differences have no relationship to the level of play of professional players. General aerobic capacity is fairly homogeneous between playing position and level of play, even if there are observable $\dot{V}_{O2\text{max}}$ differences due to inter-individual profiles.

Stølen, Chamari, Castagna and Wisløff (2005) provided an update on the physiology of soccer players and referees, and relevant physiological tests. It also gives examples of effective strength- and endurance-training programmes to improve on-field performance. The cited literature has been accumulated by computer searching of relevant databases and a review of the authors' extensive files. From a total of 9893 papers covering topics discussed in this article, 843 were selected for closer scrutiny, excluding studies where information was redundant, insufficient or the experimental design was inadequate. In this article, 181 were selected and discussed. The information may have important implications for the safety and success of soccer players and hopefully it should be understood and acted upon by coaches and individual soccer players.

Ooi et al., (2009) established the physical and physiological attributes of elite and sub-elite Malaysian male badminton players and to determine whether these attributes discriminate elite players from sub-elite players. Measurements and tests of basic anthropometry, explosive power, anaerobic recovery capacity,
badminton-specific movement agility, maximum strength, and aerobic capacity were conducted on two occasions, separated by at least one day. Our results show that elite Malaysian male badminton players are taller, heavier, and stronger than their sub-elite counterparts. The test battery, however, did not allow us to discriminate between the elite and sub-elite players, suggesting that at the elite level tactical knowledge, technical skills, and psychological readiness could be of greater importance.

Wong del and Wong (2009) provided information about the physiological characteristics of Asian elite youth soccer players (a) for strength and conditioning specialists to design training program based on players' physiological characteristics and b) for coach to design an appropriate play tactic. Sixteen Chinese elite youth male players from the U-17 national team participated in the following tests in the current study: (a) maximal vertical jump, (b) isokinetic muscular strength tests of knee joint at angular velocities of 60, 120, 180, 240, and 300 degrees x s, (c) maximal oxygen consumption ($\hat{V}_{O2}$max), (d) 1 repetition maximum (1RM) strength test, and (e) 30-m sprint. In conclusion, compared with European and African players, Asian youth players have less jump height and shorter body height. They also have poor performance in isokinetic muscular strength of quadriceps and hamstrings (especially at high speed), $\hat{V}_{O2}$max, 1RM strength test, sprint starts, and 20- to 30-m sprints. A specialized training in jumping performance, high-speed movement, muscular strength at high contraction speed, endurance running, short distance sprint (i.e., 5 m), and 20- to 30-m sprints are recommended for Asian elite youth soccer players (or players with similar physique and ability).
**Ziv and Lidor (2009)** reviewed a series of studies (n = 51) examining physical attributes, physiological characteristics, on-court performances and nutritional strategies of female and male elite basketball players. These studies included relevant information on physical and physiological variables, such as height, weight, somatotype, relative size, aerobic profile, strength, anaerobic power, agility and speed. It is concluded that the data emerging from these studies, combined with the knowledge already obtained from the studies on physical and physiological characteristics of elite basketball players, should be applied by basketball and strength and conditioning coaches when planning training programmes for elite basketball players.

**Casamichana and Castellano (2010)** examined physical, physiological, and motor responses and perceived exertion during different soccer drills. In small-sided games, the individual playing area ( ~ 275 m², ~ 175 m², and ~ 75 m²) was varied while the number of players per team was kept constant: 5 vs. 5 plus goalkeepers. Participants were ten male youth soccer players. Each session comprised three small-sided game formats, which lasted 8 min each with a 5-min passive rest period between them. A range of variables was recorded and analysed for the three drills performed over three training sessions: (a) physiological, measured using Polar Team devices; (b) physical, using GPS SPI elite devices; (c) perceived exertion, rated using the CR-10 scale; and (d) motor response, evaluated using an observational tool that was specially designed for this study. The results show that the size of the pitch should be taken into account when planning training drills, as it influences the intensity of the task and the motor response of players.
Lidor and Ziv (2010) reviewed a series of studies (n = 31) on physical attributes, physiological attributes, and on-court performances of female volleyball players. Empirical and practical knowledge emerging from studies on training-related issues in volleyball, such as body mass, fat-free mass, aerobic profile, strength, and agility and speed, should be integrated and applied when planning annual training programs for volleyball players. Based on our review, it was found that (a) players of a higher skill level are taller, somewhat heavier, and have higher vertical jump values than players of a lower level; (b) the aerobic profile of female volleyball players is similar to that of female basketball players; (c) ballistic resistance training can increase vertical jump values in female volleyball players; and (d) preseason conditioning should be conducted to prevent fatigue and reduced performance at the beginning of the season.

Studies related to Physical and Anthropometric Characteristics

Ioakimidis, Gerodimos, Kellis, Alexandris and Kellis (2004) examined maximal isometric strength characteristics of young male basketball players taking into consideration the combined effects of chronological age and sexual maturation. One hundred and twenty male basketball players, aged from 12 to 17 years divided into 6 equivalent age subgroups performed maximum bilateral isometric leg press efforts. The parameters analysed were the maximal voluntary isometric force (MVC), relative strength (MVC/body mass and MVC/fat free mass), starting strength (F50: force exerted during the first 50 ms of the contraction) and speed strength index (the ratio of maximal force to time to attain maximal force). It was concluded that, maximum absolute strength of basketball
players is significantly increased from 12 to 17 years and as sexual maturation stage increases. It also appears that body mass and fat free mass should be taken into consideration when examining age effects on strength in basketball players.

**Gabbett and Georgieff (2007)** investigated the physiological and anthropometric characteristics of junior volleyball players competing at the elite, semi-elite, and novice levels and to establish performance standards for these athletes. One hundred and fifty-three junior national (N = 14 males; N = 20 females), state (N = 16 males; N = 42 females), and novice (N = 27 males; N = 34 females) volleyball players participated in this study. Subjects underwent measurements of standard anthropometry, lower-body muscular power (vertical jump and spike jump), upper-body muscular power (overhead medicine ball throw), speed (5-m and 10-m sprint), agility (T-test), and estimated maximal aerobic power (multistage fitness test) during the competitive phase of the season, after obtaining a degree of match fitness. These findings provide normative data and performance standards for junior volleyball players competing at the elite, semi-elite, and novice levels.

**Gabbett, Kelly and Pezet (2007)** investigated the physiological, anthropometric, and skill characteristics of rugby league players and determined the relationship between physical fitness and playing ability in these athletes. Eighty-six rugby league players underwent measurements of standard anthropometry, muscular power, speed, agility (L run), and estimated maximal aerobic power (multistage fitness test). The results of this study demonstrate that selected skill characteristics but not physiological or anthropometric
characteristics discriminate between successful and less successful rugby league players. These findings suggest that while physiological and anthropometric characteristics do not discriminate between successful and less successful rugby league players, a high level of physical fitness contributes to effective playing ability in these athletes.

Granados, Izquierdo, Ibañez, Bonnabau and Gorostiaga (2007) compared physical characteristics (body height [BH], body mass [BM], body fat [BF], and fat free mass [FFM]), one repetition maximum bench press (1RM (BP)), jumping explosive power (VJ), handball throwing velocity, power-load relationship of the leg and arm extensor muscles, 5- and 15-m sprint running time, and running endurance in elite (n = 16; EF) and amateur (n = 15; AF) female handball players aged 17 - 38. It was concluded that, the higher absolute values of maximal strength and muscle power, although explained by the differences in fat free mass, will give EF an advantage to sustain certain handball game actions.

Cavala, Rogulj, Srhoj, Srhoj and Katić (2008) identified biomotor structures in elite female handball players, factor structures of morphological characteristics and basic motor abilities, and of variables evaluating situation motor abilities of elite female handball players (n = 53) were determined first, followed by determination of differences and relations of the morphological, motor and specific motor space according to handball performance. Factor analysis of 16 morphological measures produced three morphological factors, i.e. factor of absolute voluminosity, i.e. mesoendomorphy, factor of longitudinal skeleton dimensionality, and factor of transverse hand dimensionality. Factor
analysis of 15 motor variables yielded five basic motor dimensions, i.e. factor of agility, factor of throwing explosive strength, factor of running explosive strength (sprint), factor of jumping explosive strength and factor of movement frequency rate. Factor analysis of 5 situation motor variables produced two dimensions: factor of specific agility with explosiveness and factor of specific precision with ball manipulation. It was concluded that, concerning basic motor abilities, the factor of movement frequency rate, which is associated with the ability of ball manipulation, was observed to predict significantly the handball players' performance.

Granados, Izquierdo, Ibáñez, Ruesta and Gorostiaga (2008) examined the effects of an entire season on anthropometric characteristics, physical fitness, and throwing velocity. One-repetition-maximum bench press (1RMBP), jumping explosive strength, power-load relationship of the leg and arm extensor muscles, 5- and 15-m sprint running time, endurance running, and handball throwing velocity were assessed in four periods. Individual volumes and intensities of training and competition were quantified for 11 activities. It was concluded that, the handball season resulted in significant increases in anthropometric characteristics, physical fitness, and throwing velocity. The correlations observed suggest the importance of including explosive strength exercises of the knee and elbow extensions. Special attention may be needed to be paid to the mode of body fat loss, to increase endurance capacity without interfering in strength gains.

Sheppard et al., (2008) examined the potential strength, power, and anthropometric contributors to vertical jump performances that are considered
specific to volleyball success: the spike jump (SPJ) and counter-movement vertical jump (CMVJ). To assess the relationship among strength, power, and anthropometric variables with CMVJ and SPJ, a correlation and regression analysis was performed. In addition, a comparison of strength, power, and anthropometric differences between the seven best subjects and the seven worst athletes on the CMVJ test and SPJ test was performed. The results of this study clearly demonstrate that in an elite population of volleyball players, stretch-shortening cycle performance and the ability to tolerate high stretch loads, as in the depth jump, is critical to performance in the jumps associated with volleyball performance.

**Carling, Le Gall, Reilly and Williams (2009)** examined whether maturity, anthropometric profiles and fitness measures vary according to birth date distribution in elite, under-14 youth academy soccer players. The selection year was divided into four quarters, with 160 male players grouped according to individual birth date. Players had their skeletal age determined and were assessed using a battery of standard anthropometric and physical performance tests. These findings suggest that the relative age of the performer may not always be linked to a significant advantage in physical components. The selection criteria for entry into the academy may explain the present results.

**Girard and Millet (2009)** examined the relationships between speed, explosive power, leg stiffness, and muscular strength of upper and lower limbs; and determined to what extent these physical qualities relate to tournament play performance in a group of competitive teenage tennis players. A total of 12 male
players aged 13.6 +/- 1.4 years performed a series of physical tests: a 5-m, 10-m, and 20-m sprint; squat jump (SJ); countermovement jump (CMJ); drop jump (DJ); multi-rebound jumps; maximum voluntary contraction of isometric grip strength; and plantar flexor of the dominant and nondominant side. It seems that physical attributes have a strong influence on tennis performance in this age group and that an important asymmetry is already observed. By monitoring regularly such physical abilities during puberty, the conditioning coach can modify a program to compensate for the imbalances.

Gorostiaga et al. (2009) compared anthropometric (body height, body mass, percent body fat, fat-free body mass) and physical fitness characteristics (vertical jump height, power-load curve of the leg, 5 and 15 m sprint running time and blood lactate concentrations ([La](b)) at submaximal running velocities) among 15 elite male indoor soccer (IS) and 25 elite male outdoor soccer (OS) players. The present results show that compared to elite OS players, elite IS players present clearly lower physical fitness (lower maximal leg extension power production) characteristics associated with higher values of percent body fat.

Marques, Van den Tillaar, Gabbett, Reis and González-Badillo (2009) investigated the anthropometric and strength characteristics of elite male volleyball athletes and to determine if differences exist in these characteristics according to playing position. A group of 35 professional male team volleyball players participated in the study. Players were categorized according to playing position and role: middle blockers (n = 9), opposite hitters (n = 6), outside hitters (n = 10), setters (n = 6), and liberos (n = 4). Height, body mass, muscular strength
and muscular power were assessed. Significant differences (p < 0.05) were found among the 5 positional categories. These results demonstrate that significant anthropometric and strength differences exist among playing positions in elite male volleyball players.

**Tan, Polglaze, Dawson and Cox (2009)** investigated the anthropometric and fitness characteristics of elite female water polo players and examine the differences between players of different competition levels. Twenty-six female water polo players underwent measurements of standard anthropometry, lower-body muscular power (in-water vertical jump), speed (10-m maximal sprint swim), and aerobic fitness (multistage shuttle swim test). No goalkeepers were involved. These findings demonstrate that anthropometric and fitness characteristics can discriminate between players of different competition levels and playing positions.

**Chelly, Hermass and Shephard (2010)** investigated relationships between peak power (PP) as measured by upper limb (PPUL) and lower limb (PPLL) force-velocity tests, maximal upper limb force assessed by 1 repetition maximum bench press (1RMBP), and pullover (1RMPO) exercises, estimates of local muscle volume and 3-step running handball throwing velocity (T3-Steps). Our results also highlight the contribution of both the lower and the upper limbs to handball throwing velocity, suggesting the need for coaches to include upper and lower limb strength and power programs when improving the throwing velocity of handball players.
**Le Gall, Carling, Williams and Reilly (2010)** compared anthropometric and fitness performance data from graduate male youth players from an elite soccer academy who on leaving the institution were either successful or not in progressing to higher standards of play. Altogether, 161 players were grouped according to whether they achieved international or professional status or remained amateur. Measures were taken across three age categories (under 14, 15 and 16 years of age). Players were assessed using standard measures of anthropometric and fitness characteristics. These results suggest that anthropometric and fitness assessments of elite youth soccer players can play a part in determining their chances of proceeding to higher achievement levels.

**Tsolakis, Kostaki and Vagenas (2010)** investigated selected structural correlates of fencing performance. 33 elite fencers were tested on (a) selected anthropometric, flexibility, and strength-power related parameters, and (b) specific lower extremity functional fencing tests. Multiple regression showed that drop jump and thigh cross-sectional area were best predictors of lunge time and distance of squat jump on the shuttle test. When the two performance variables were expressed per Lean Body Mass, lunge time was significantly predicted only by the performance on the arm-driven counter-movement jump, while time on the shuttle test was best predicted by three noncollinear significant predictors: squat jump performance, thigh circumference, and percent body fat. Lunge time and time on the shuttle test were predicted by explosive power, while none of the nontrainable anthropometric measures or years of training seemed to be important in performance of fencing-related skills.
Studies related to Physical and Performance Related Characteristics

Ugarkovic, Matavulj, Kukolj and Jaric (2002) investigated whether variables routinely assessed while testing athletes can also predict movement performance. The relation between jumping performance and standard strength, anthropometric, and body composition variables was examined in elite junior basketball players. The 33 males were tested for maximal vertical jump, as well as for maximal isometric voluntary force and rate of force development of hip and knee extensors. Standard anthropometric and body composition measures were also taken. The results obtained dispute the use of the examined tests in sport performance assessment, and also question applying the tests for other purposes such as evaluation of training procedures or selection of young athletes. Therefore, the results are in line with the concept that a reliable performance assessment in homogeneous groups of athletes requires predominantly movement-specific testing.

Ostojic, Mazic and Dikic (2006) described structural and functional characteristics of elite Serbian basketball players and to evaluate whether players in different positional roles have different physical and physiological profiles. Five men's basketball teams participated in the study and competed in the professional First National League. Physiological measurements were taken of 60 players during the final week of their preparatory training for competition. The results of the present study demonstrate that a strong relationship exists between body composition, aerobic fitness, anaerobic power, and positional roles in elite basketball.
Cormery, Marcil and Bouvard (2007) evaluated by examining data collected on professional basketball players during a 10-year period, the differences in aerobic capacity in function of the playing position and the impact on these parameters of the change in time regulation of 2000, which shortened the time allowed to attempt a field goal by 6 s and divided the duration of play in four quarters. Twice a year between 1994 and 2004, professional basketball players (n = 68) were studied for anthropometric characteristics and were submitted to an incremental exercise test on a cycle ergometer. Statistical analyses were carried out to determine the interaction between the playing position and the effect of the change in time regulation on the physiological characteristics of the players. In conclusion, while anthropometric characteristics remained constant during the last decade, the change in rule of 2000 may have contributed in modifying the physiological profile of basketball players, by generally increasing their level of fitness.

Baker and Newton (2008) compared the lower body strength, power, acceleration, maximal speed, agility, and sprint momentum of elite first-division national rugby league (NRL) players (n = 20) to second-division state league (SRL) players (n = 20) players from the same club. Strength and maximal power were the best discriminators of which players were in the NRL or SRL squads. None of the sprinting tests, such as acceleration (10-m sprint), maximal speed (40-m sprint), or a unique 40-m agility test, could distinguish between the NRL or SRL squads. However, sprint momentum, which was a product of 10-m velocity and body mass, was better for discriminating between NRL and SRL players as heavier, faster players would possess better drive forward and conversely be better
able to repel their opponents’ drive forward. It was concluded that, strength and conditioning specialists should therefore pay particular attention to increasing lower body strength and power and total body mass through appropriate resistance training while maintaining or improving 10-m sprint speed to provide their players with the underlying performance characteristics of play at the elite level in rugby leagues.

Argus, Gill, Keogh, Hopkins and Beaven (2009) assessed changes in strength, power, and levels of testosterone and cortisol over a 13-week elite competitive rugby union season. Thirty-two professional rugby union athletes from a Super 14 rugby team were assessed for upper-body and lower-body strength (bench press and box squat, respectively) and power (bench throw and jump squat, respectively) up to 5 times throughout the competitive season. Salivary testosterone and cortisol samples, along with ratings of perceived soreness and tiredness, were also obtained before each power assessment. It was concluded that, positive adaptation in strength and power may be primarily affected by cumulative training volume and stimulus over a competitive season. Greater than 2 resistance sessions per week may be needed to improve strength and power in elite rugby union athletes during a competitive season.

Crewther, Lowe, Weatherby, Gill and Keogh (2009) compared the neuromuscular performance (speed, power, strength) of elite rugby union players, by position, and examined the relationship between player performance and salivary hormones, by squad and position. Thirty-four professional male rugby players were assessed for running speed (10-m, 20-m or 30-m sprints), concentric
mean (MP) and peak power (PP) during a 70-kg squat jump (SJ) and 50-kg bench press throw (BT), and estimated 1 repetition maximum (1RM) strength for a box squat (BS) and bench press (BP). Based on these findings, it was suggested that training to increase whole-body and muscle mass might facilitate general performance improvements. Training prescription might also benefit from acute and chronic hormone monitoring to identify those individuals likely to respond more to hormonal change.

Delextrat and Cohen (2009) investigated the effect of playing position on strength, power, speed, and agility performances of women basketball players. Thirty subjects playing at national level participated in this study. They were divided into 3 groups according to playing position: guards (positions 1 and 2), forwards (positions 3 and 4), and centers (position 5). Each subject performed 8 tests presented in a random order: These results indicate that specific fitness training must be undertaken according to playing position. The ability to perform the suicide run, the single-leg jump, and the different movements involved in the agility T-test must be developed in guards. In contrast, speed over short distances and strength development of lower body and upper body should be performed by all playing positions.

Gabbett (2009) investigated the physical qualities of junior rugby league players (Under 14, 16, and 18) and determine if preseason fitness measures were significantly different for the players selected to play in the first competitive game of the season (i.e. starters) compared to the players not selected (i.e. non-starters). Eighty-eight junior (N.=53 Under 14; N.=20 Under 16; N.=15 Under 18) subelite
rugby league players participated in this study. All players were registered with the same junior recreational rugby league club. Subjects underwent measurements of anthropometry (height, body mass, and sum of four skinfolds), speed (10-m, 20-m, and 40-m sprint), change of direction speed (505 test), estimated lower body power (vertical jump), and estimated maximal aerobic power (multi-stage fitness test) at the beginning of the competitive season. These findings demonstrate that junior rugby league players selected to the starting team have better developed physical qualities than non-starting players. Coaches should emphasize the development of speed, change of direction speed, and aerobic qualities in junior rugby league players.

**Kaplan, Erkmen and Taskin (2009)** determined the running speed and agility performance by playing positions. The sample included 108 professional male soccer players at the national level and 79 amateur male soccer players at a regional level on teams from 10 clubs in Turkey. The study involved the players being assessed by the 10- x 5-m shuttle run test ( 10 x 5 SRT) on a soccer field in a soccer season. In conclusion, professional soccer players' running speed and agility performances are higher than amateur soccer players. In addition, these results indicate that all soccer players have the same running speed and agility performance in accordance with their different playing positions. Coaches should consider individual training programs based on the positional role of soccer players.

**Ben Abdelkrim et al., (2010)** examined the demands of competitive basketball games and to study the relationship between athletes' physical
capability and game performance. Physical and physiological game demands and
the association of relevant field test with game performance were examined in 18
male junior basketball players. Computerized time-motion analysis, heart rate
(HR), and blood-lactate concentration [BL] measurements were performed during
6 basketball games. Players were also measured for explosive power, speed,
agility, and maximal-strength and endurance performance. This study showed that
basketball players experience fatigue as game time progresses and suggests the
potential benefit of aerobic and agility conditioning in junior basketball.

Ben Abdelkrim, Chaouachi, Chamari, Chtara and Castagna (2010)
compared the physical attributes of elite men's basketball players according to age
and specific individual positional roles. Forty-five players from three national
basketball teams (Under-18 years, Under-20 years, and Senior) were measured for
anthropometry (height, body mass, percentage body fat), explosive power (5
jumps and vertical jump), speed (5-m, 10-m, and 30-m sprint), agility (T-test),
strength (bench press and squat 1 repetition maximum [1RM]), and intermittent
high-intensity endurance performance (Yo-Yo intermittent recovery test [Yo-Yo
IR1]). Data on match frequency, training routines, and playing experience were
also collected. These results showed the existence of age and positional role
differences in fitness performance in men's basketball. Differences were
particularly evident in intermittent high-intensity endurance and agility
performance. Sprint training possibly should be individualized when dealing with
positional roles in elite men's basketball.
Brechue, Mayhew and Piper (2010) investigated sprinting strategy, acceleration and velocity patterns were determined in college football players (n = 61) during performance of a 9.1-, 36.6-, and 54.9-m sprints. Acceleration and velocity were determined at 9.1-m intervals during each sprint. Lower-body strength and power were evaluated by 1 repetition maximum (1-RM) squat, power clean, jerk, vertical jump, standing long jump, and standing triple jump. It was concluded that, the acceleration and velocity patterns were the same for each position group, and differences in sprint time were determined by the magnitude of acceleration and velocity at 9.1 and 18.3 m. Sprint performance in football players is determined by a rapid increase in acceleration (through 18.3 m) and a high velocity maintained throughout the sprint and is independent of position played.

Dupler, Amonette, Coleman, Hoffman and Wenzel (2010) examined physical and performance differences between grade levels and playing positions within High-School football players. Two thousand three hundred and twenty-seven athletes were tested for height, weight, 40-yd sprint time, proagility time, and vertical jump height. Mean scores across age groups and playing positions were compared using repeated-measures analysis of variance (ANOVA) and 1-way ANOVAs. Overall, these data suggest that there are distinct differences in the physical and performance characteristics of high-school football players. The greatest difference is observed between the sophomore and junior years. Older, more mature athletes are faster, quicker, and capable of generating more power than younger athletes.
Erčulj, Blas and Bračič (2010) determined and analyze the level of certain motor abilities (acceleration and agility, the explosive strength of arms, and take-off power) of young elite European female basketball players. We also wanted to establish whether there were any differences between 3 groups of female basketball players who differed in terms of their playing performance. The sample of subjects consists of 65 female basketball players aged 14.49 (± 0.61) years who were divided into 3 groups (divisions A, B, and C of the European Championships). The findings of this study will enable the generation of model values, which can assist basketball coaches for this age category in basketball clubs, high schools, national teams, and basketball camps.

Studies related to Physiological Characteristics

Apostolidis, Nassis, Bolatoglou and Geladas (2004) described the physiological and technical characteristics of elite young basketball players, and b) to examine the relationship between certain field and laboratory tests among these players. Thirteen male players of the junior's Basketball National team performed a run to exhaustion on the treadmill, the Wingate test and 2 types of vertical jump. On a separate day, the field tests (control dribble, defensive movement, speed dribble, speed running, shuttle run and dribble shuttle run) were conducted. It was concluded that, these players presented a moderate $\dot{V}_{\text{O}_2}\text{max}$ and anaerobic power. The significant correlation between Pmean and certain field tests indicates that these tests could be used for the assessment of anaerobic capacity of young basketball players.
Gorostiaga, Granados, Ibáñez and Izquierdo (2005) compared physical characteristics (body height, body mass [BM], body fat [BF], and free fatty mass [FFM]), one repetition maximum bench-press (1RM (BP)), jumping explosive strength (VJ), handball throwing velocity, power-load relationship of the leg and arm extensor muscles, 5- and 15-m sprint running time, and running endurance in two handball male teams: elite team, one of the world's leading teams (EM, n = 15) and amateur team, playing in the Spanish National Second Division (AM, n = 15). It was concluded that, the differences observed in free fatty mass could partly explain the differences observed between groups in absolute maximal strength and muscle power. In EM, higher efficiency in handball throwing velocity may be associated with both upper and lower extremity power output capabilities, whereas in AM this relationship may be different.

Castagna, D'Ottavio, Granda Vera, Barbero Alvarez (2009) examined the physiological responses and activity pattern to Futsal simulated game-play in professional players. Eight full-time professional outfield Futsal players volunteered for this study: age 22.4 (95% CI 18.8-25.3) years, body mass 75.4 (60-91) kg, height 1.77 (1.59-1.95) m and \( \dot{V}_\text{O}_2\text{max} \) 64.8 (53.8-75.8) ml kg(-1) min(-1). Physiological measurements were assessed during highly competitive training games (4x10-min quarters) and consisted of game \( \dot{V}_\text{O}_2 \), game blood-lactate concentration ([la](b)) and game heart rates (HRs). These results show that Futsal played at professional level is a high-intensity exercise heavily taxing the aerobic and anaerobic pathways.

Mirzaei, Curby, Rahmani-Nia and Moghadasi (2009) described the physiological profile of elite Iranian junior freestyle wrestlers. Seventy elite
wrestlers (age 19.8 +/- 0.9 years) who were invited to the national training camps, based on their top 10 national ranking, participated in this study. The physiological profile included body weight, flexibility (sit and reach test), maximal oxygen consumption (Bruce protocol), maximal anaerobic power of the legs (Wingate test), muscular endurance and strength, speed (40-m sprint), agility (4 x 9-m shuttle run), and body composition (7-site skinfold). The present study provides baseline physiological data that have been used in the prescription of individual training programs for these athletes. This information is also available to the coaches and can contribute to the general strategy employed by a wrestler and for a specific match.

**Wells, Elmi and Thomas (2009)** identified physiological correlates of golf performance in elite golfers under laboratory (ball speed and distance) and tournament conditions. The correlation analysis revealed significant associations between mass, height, body mass index, sit height, arm length, and predicted $\hat{V}_{02}$max and golf measures. Results suggest that core strength and stability, flexibility, balance, and peripheral muscle strength are correlated with golf performance and should be included in golf training programs.

**Gabbett, Jenkins and Abernethy (2010)** investigated the physiological and skill demands of 'on-side' and 'off-side' games in elite rugby league players. Sixteen male rugby league players participated in 'on-side' and 'off-side' games. Both small-sided games were played in a 40- x 40-m playing area. The 'off-side' game permitted players to have 3 'plays' while in possession of the ball. Players were permitted to pass backward or forward (to an 'off-side' player). The 'on-side' game also permitted players to have 3 'plays' while in possession of the ball.
However, players were only permitted to pass backward to players in an 'on-side' position. Heart rate and movement patterns (via global positioning system) were recorded continuously throughout both games. The results of this study demonstrate that 'off-side' games provide greater physiological and skill demands than 'on-side' games. 'Off-side' games may provide a practical alternative to 'on-side' games for the development of skill and fitness in elite rugby league players.

Hill-Haas, Coutts, Dawson and Rowsell (2010) examined acute physiological responses and time-motion characteristics associated with 4 soccer-specific small-sided game (SSG) formats (3 vs. 4 players, 3 vs. 3 players + floater, 5 vs. 6 players, and 5 vs. 5 players + floater) and 4 rule changes in elite youth soccer players. Sixteen male youth soccer players participated in the study, in which heart rate (HR), rating of perceived exertion (RPE), blood lactate (La), and time-motion characteristics were recorded. The major practical findings are that subtle changes in SSGs playing rules can influence the physiological, perceptual, and time-motion responses in young elite soccer players. Rules that are related to a team's chances of scoring may improve player motivation and thereby increase training intensity during SSGs. There were no differences between fixed and variable formats in terms of physiological and perceptual responses, although both may provide useful technical-tactical training. Coaches should take care in designing different soccer SSGs as each rule or game format change may influence exercise intensity independently.

Hill-Haas, Dawson, Impellizzeri and Coutts (2011) discussed the physiology of small sided games. The variation of exercise intensity measures are lower in smaller game formats (e.g. three vs three) and have acceptable
reproducibility when the same game is repeated between different training sessions or within the same session. The variation in exercise intensity during SSGs can also be improved with consistent coach encouragement but it is still more variable than traditional generic training methods. Other studies have also shown that SSGs containing fewer players can exceed match intensity and elicit similar intensities to both long- and short-duration high-intensity interval running. It also appears that fitness and football-specific performance can be improved equally with SSG and generic training drills.

**Studies related to Physiological and Anthropometric Characteristics**

**Gabbett (2000)** investigated the physiological and anthropometric characteristics of amateur rugby league players. Thirty five amateur rugby league players (19 forwards and 16 backs) were measured for height, body mass, percentage body fat (sum of four skinfolds), muscular power (vertical jump), speed (10 m and 40 m sprint), and maximal aerobic power (multistage fitness test). Data were also collected on match frequency, training status, playing experience, and employment related physical activity levels. These findings suggest that position specific training does not occur in amateur rugby league. The poor fitness of non-elite players may be due to a low playing intensity, infrequent matches of short duration, and/or an inappropriate training stimulus.

**Hoare (2000)** measured anthropometric and physiological attributes of 125 male and 123 female junior basketball players competing at the Australian Under 16 championships in 1998. In addition, experienced coaches rated the performance of players during the championships. Performance profiles were
compared across playing positions and by playing performance ('Best versus Rest'). Differences in anthropometric characteristics were present across some playing positions for both males and females. Speed and agility differences between some playing positions were also present. Best players differed to Rest players on a number of anthropometric and physiological variables for both males and females. Regression analyses indicated that anthropometric and physiological profiling can contribute to selection procedures in junior basketball, however determinants of success are multi-factorial.

Reilly, Bangsbo and Franks (2000) focused on anthropometric and physiological characteristics of soccer players with a view to establishing their roles within talent detection, identification and development programmes. Top-class soccer players have to adapt to the physical demands of the game, which are multifactorial. Players may not need to have an extraordinary capacity within any of the areas of physical performance but must possess a reasonably high level within all areas. The positional role of a player is related to his or her physiological capacity. Thus, midfield players and full-backs have the highest maximal oxygen intakes (\( > 60 \, \text{ml x kg}^{-1} \times \text{min}^{-1} \)) and perform best in intermittent exercise tests. On the other hand, midfield players tend to have the lowest muscle strength. Although these distinctions are evident in adult and elite youth players, their existence must be interpreted circumspectly in talent identification and development programmes. We conclude that anthropometric and physiological criteria do have a role as part of a holistic monitoring of talented young players.
Gabbett (2005) compared the physiological and anthropometric characteristics of specific playing positions and positional playing groups in junior rugby league players. Two hundred and forty junior rugby league players underwent measurements of standard anthropometry (body mass, height, sum of four skinfolds), muscular power (vertical jump), speed (10, 20, and 40 m sprint), agility (L run), and estimated maximal aerobic power (multi-stage fitness test) during the competitive phase of the season, after players had obtained a degree of match fitness. The results of this study demonstrate that few physiological and anthropometric differences exist among individual playing positions in junior rugby league players, although props are taller, heavier, have greater skinfold thickness, lower 20 and 40 m speed, agility, and estimated maximal aerobic power than other positional playing groups.

Gabbett (2006) compared the physiological and anthropometric characteristics of specific playing positions and positional playing groups in subelite rugby league players. Altogether, 415 sub-elite rugby league players underwent measurements of standard anthropometry (body mass, height, sum of four skinfolds), muscular power (vertical jump), speed (10-m, 20-m, and 40-m sprint), agility ("L" run), and estimated maximal aerobic power (multi-stage fitness test). The results of this study demonstrate that few physiological and anthropometric differences exist among individual playing positions in sub-elite rugby league players, although props are taller, heavier, have greater skinfold thickness, slower 10-m and 40-m speed, less agility, and lower estimated maximal aerobic power than other positional groups.
Gabbett (2007) investigated the physiological and anthropometric characteristics of elite women rugby league players and developed physical performance standards for these athletes. Thirty-two elite women rugby league players underwent measurements of standard anthropometry (body mass, height, sum of 7 skinfolds), muscular power (vertical jump), speed (10-, 20-, and 40-m sprint), agility (505 test), glycolytic capacity (glycolytic agility test), and estimated maximal aerobic power (multistage fitness test). These findings show the need to develop all physiological parameters to allow elite women rugby league players to more effectively tolerate the physiological demands of competition, reduce fatigue-related errors in skill execution, and decrease the risk of injury.

Gabbett, Kelly and Pezet (2007) investigated the physiological, anthropometric, and skill characteristics of rugby league players and determined the relationship between physical fitness and playing ability in these athletes. Eighty-six rugby league players underwent measurements of standard anthropometry, muscular power, speed (10-, 20-, and 40-m sprint), agility (L run), and estimated maximal aerobic power (multistage fitness test). The results of this study demonstrate that selected skill characteristics but not physiological or anthropometric characteristics discriminate between successful and less successful rugby league players. However, all physiological and anthropometric characteristics were related to playing ability.

Gil, Gil, Ruiz, Irazusta & Irazusta (2007) established the anthropometric and physiological profiles of young nonelite soccer players according to their
playing position, and to determine their relevance for the selection process. Two
hundred forty-one male soccer players who were members of the Getxo Arenas
Club (Bizkaia) participated in this study. Participants performed the Astrand test
to estimate their absolute and relative $\dot{V}_{O2}max$, an endurance test, sprint tests and 3
jump tests. Forwards were the leanest, presenting the highest percentage of
muscle. Thus, it may conclude that anthropometric and physiological differences
exist among soccer players who play in different positions. These differences fit
with their different workload in a game. Therefore, training programs should
include specific sessions for each positional role.

Gil, Ruiz, Irazusta, Gil and Irazusta (2007) described the
anthropometric and physiological characteristics of young soccer players (14-17
years old) which were associated with their being successful or not as soccer
players. Somatotype and body composition was calculated by measuring
skinfolds, limb circumferences and joint diameters. $\dot{V}_{O2}max$ was estimated by the
Astrand's Test. Sprint, jump and endurance tests were also performed. These
results indicate that around the time of puberty, parameters associated with
physical maturity such as height, size, speed, $\dot{V}_{O2}max$, or chronological age are
important to determine the success of a soccer player. At older ages, other factors
such as agility seem to be more important. Nevertheless, players born in the 1st
semester of the year are also more frequent in the older teams.

Chaouachi et al., (2009) tested anthropometric, physiological, and
performance characteristics of an elite international handball team. Twenty-one
elite handball players were tested and categorized according to their playing
positions (goalkeepers, backs, pivots, and wings). Testing consisted of anthropometric and physiological measures of height, body mass, percentage body fat and endurance (VO\(_{2}\max\)), performance measures of speed (5, 10, and 30 m), strength (bench press and squat), unilateral and bilateral horizontal jumping ability, and a 5-jump horizontal test. In conclusion, performance abilities between positions in elite team-handball players appear to be very similar. Single leg horizontal jumping distance could be a specific standardized test for predicting sprinting ability in elite handball players.

Wong, Chamari, Dellal and Wisløff (2009) examined the relationship between anthropometric and physiological performances among youth soccer players and the positional differences for these variables. Seventy U14 male soccer players participated in this study. This study provides a scientific rationale behind the coaches' practice of selecting young soccer players according to their anthropometry for short-term benefits such as heavier players for higher ball shooting speed and 30-m sprint ability as an example. However, this does not justify such practice in the long-term process of player development.

Gabbett, Jenkins and Abernethy (2010) investigated the tackling ability of junior elite and subelite rugby league players, and determined the relationship between selected physiological and anthropometric characteristics and tackling ability in these athletes. Twenty-eight junior elite and 13 junior subelite rugby league players underwent a standardized 1-on-1 tackling drill in a 10-m grid. Video footage was taken from the rear, side, and front of the defending player. These findings demonstrate that fast acceleration, and to a lesser extent, lower
body muscular power contribute to effective tackling ability in junior rugby league players.

Studies related to Physiological and Performance Related Characteristics

Davis, Brewer and Atkin (1992) investigated physiological characteristics of soccer players and to relate them to positional roles. A total of 135 footballers (age 24.4 +/- 4.6 years) were assessed for body mass, % body fat, haemoglobin, maximal oxygen uptake (\( \dot{V}_{O2} \text{max} \)), leg power, anaerobic capacity and speed prior to an English league season. The sample included 13 goalkeepers, 22 full-backs, 24 centre-backs, 35 midfield players and 41 forwards. It was concluded that, anaerobic power, as well as knee extensor torques (corrected for body mass) and extensor-flexor ratios, were similar between groups. No difference in estimated body fat percentage was observed between any of the outfield players, and haemoglobin concentrations were similar among players of all positions.

Brewer and Davis (1995) discussed physiology rugby players. Maximum oxygen uptake (\( \dot{V}_{O2} \text{max} \)) values of around 56 ml/kg/min have been reported for rugby league players, with no differences between the values of forwards and backs. Forwards have, however, been shown to generally have higher body mass, subcutaneous fat and fat-free mass levels than backs. Backs have been found to be quicker than forwards and produce greater leg power output when related to fat-free mass. The amount of physiological data on rugby league players and the sport of rugby league is very limited, and there is considerable scope for future research in this area.
Nicholas (1997) discussed with the increased physiological demands being placed on the elite players (using the British Isles as an example), with the recent introduction of professionalism, regional championships, the World Cup and major tours, information about the demands of the game and the assessment of, and methods of improving, the anthropometric and physiological characteristics of its players, are of paramount importance. Match analysis has indicated that rugby is an interval or intermittent sport and players must be able to perform a large number of intensive efforts of 5 to 15 seconds' duration with less than 40 seconds' recovery between each bout of high intensity activity. The results from studies reporting the anthropometric and physiological characteristics of rugby union players observed that these individuals had unique anthropometric and physiological attributes which depended on positional role and the playing standard.

Gabbett (2005) provided comprehensive review of the science of rugby league football at all levels of competition (i.e. junior, amateur, semi-professional, professional), with special reference to all discipline-specific scientific research performed in rugby league (i.e. physiological, psychological, injury epidemiology, strength and conditioning, performance analysis). Rugby league football is played at junior and senior levels in several countries worldwide. More recently, studies have investigated the physiological demands of competition. Interestingly, the physiological capacities of players, the incidence of injury and the physiological demands of competition all increase as the playing standard is increased. Mean blood lactate concentrations of 5.2, 7.2 and 9.1 mmol . I(-1) have been reported during competition for amateur, semi-professional and professional rugby league
players respectively. Mean heart rates of 152 beats \cdot \text{min}^{-1} (78\% \text{ of maximal heart rate}), 166 \text{ beats} \cdot \text{min}^{-1} (84\% \text{ of maximal heart rate}) and 172 \text{ beats} \cdot \text{min}^{-1} (93\% \text{ of maximal heart rate}) have been recorded for amateur, semi-professional and junior elite rugby league players respectively.

\textbf{Sporis, Jukic, Ostojic and Milanovic (2009)} evaluated whether players in different positional roles have a different physical and physiologic profile. For the purpose of this study, physiologic measurements were taken of 270 soccer players during the precompetitive period of 2005/06 and the precompetitive period of 2006/07. According to the positional roles, players were categorized as defenders (n = 80), midfielders (n = 80), attackers (n = 80), and goalkeepers (n = 30). Coaches are able to use this information to determine which type of profile is needed for a specific position. It is obvious that players in different positions have different physical and physiologic profiles. Experienced coaches can use this information in the process of designing a training program to maximize the fitness development of soccer players with one purpose only, to achieve success in soccer.

\textbf{Fernandez-Gonzalo et al., (2010)} offered some insight into the factors contributing to success in this sport and to describe how physiological and technical performance evolves in young soccer players. Soccer technical skills during match play, maximum voluntary isometric contraction and power of lower limbs, jumping ability and endurance parameters were assessed in 30 prepubescent male soccer players with the same experience in soccer training. Subjects were divided into 2 groups of 15 children, a younger group (YG), aged
9.4 +/- 0.3 years, and an older group (OG), aged 11.8 +/- 0.2 years. Correlations between technical and physiological parameters were also described. The differences found between groups showed that most physical capacities that were measured here have an important increase during the first stages of puberty, pointing out that a specific training at these ages is necessary to get an appropriate basis for future performance. Besides, over 30% of the technical performance measured in this study can be explained with the physiological parameters.

**McLellan, Lovell and Gass (2011)** examined the physiological demands of competitive Rugby League match play using portable Global Positioning Systems (GPSs) to monitor players' movement patterns and heart rate (HR) and (b) examine positional comparisons to determine if players' physiological requirements are influenced by their playing position during Rugby League match play. Twenty-two elite male Rugby League players were monitored during 5 regular season competition matches using portable GPS software. There was no difference in the total distance traveled between backs (5,573 ± 1,128 m) and forwards (4,982 ± 1,185 m) during match play. The GPS successfully provided real-time feedback to identify significant positional differences in distances covered, running speed characteristics, and the physiological demands of competitive Rugby League match play.

**Waldron, Twist, Highton, Worsfold and Daniels (2011)** discussed physiological match demands of elite rugby league using portable global positioning systems. Twelve elite players from an English Super League club consented to participate in the present study using portable global positioning
system (GPS) devices to assess position-specific demands. Results support the requirement for position-specific conditioning and provide preliminary evidence for the use of session ratings of perceived exertion as a measure of match load.

Studies related to Anthropometric and Performance related Characteristics

Bayios, Bergeles, Apostolidis, Noutsos and Koskolou (2006) determined the anthropometric profile, body composition and somatotype of elite Greek female basketball (B), volleyball (V) and handball (H) players, b) and compared the mean scores among sports and c) to detect possible differences in relation to competition level. A total of 518 female athletes, all members of the Greek first National League (A1 and A2 division) in B, V and H sport teams participated in the present study. Twelve anthropometric measures required for the calculation of body composition indexes and somatotype components were obtained according to the established literature. It was concluded that, anthropometric, body composition and somatotype variables of Greek female elite teamball players varied among sports; selection criteria, hours of training and sport-specific physiological demands during the game could explain the observed differences.

Visnapuu and Jürimäe (2008) investigated the relationships between basic body and specific hand anthropometric parameters with some specific and non-specific throw test results in young male handball and basketball players. The subjects included 34 handball and 38 basketball players of the 10-11 years old age group, 39 handball and 22 basketball players of the 12-13 years old age group and 39 handball players of the 14-15 years old age group. Our conclusion is that the basic anthropometric parameters are slightly more important than hand
anthropometry that influenced different throw tests results in young handball and basketball players.

Zampagni et al., (2008) determined the relationships between performance times and age, body mass, height, arm length, forearm length, forearm muscle volume, and hand grip strength were examined in 135 elite master swimmers. Pearson's simple correlation coefficients were calculated and then prediction equations were developed. Age, height, and hand grip strength were the best predictors in short-distance events, whereas only age and height were predictors in middle- and long-distance events. It was concluded that, differences between sexes were not found in 50-m event, but were present in all other events. These models might be useful to determine individual performance times by contributing to improving the individual's training program and the selection of master swimmers.

Hoffman, Vazquez, Pichardo and Tenenbaum (2009) compared anthropometric and performance variables in professional baseball players and examined the relationship between these variables and baseball-specific performance. During a 2-year period, 343 professional baseball players were assessed for height, weight, body composition, grip strength, vertical jump power, 10-yard sprint speed, and agility. Results indicated that both anthropometric and performance variables differed between players of different levels of competition in professional baseball. Agility, speed, and lower-body power appeared to provide the greatest predictive power of baseball-specific performance.
Gall, Carling, Williams and Reilly (2010) compared anthropometric and fitness performance data from graduate male youth players from an elite soccer academy who on leaving the institution were either successful or not in progressing to higher standards of play. Altogether, 161 players were grouped according to whether they achieved international or professional status or remained amateur. Measures were taken across three age categories (under 14, 15 and 16 years of age). Players were assessed using standard measures of anthropometric and fitness characteristics. The skeletal age of players was also measured to determine maturity status. These results suggest that anthropometric and fitness assessments of elite youth soccer players can play a part in determining their chances of proceeding to higher achievement levels.

Summary of Literature

The studies reviewed illustrate that there are many anthropometrical, biomotor, physical, physiological and psychological characteristics of players in various sports and games. These studies show that regardless of current fitness status, mind-body interventions can be successful in improving the fitness and wellness status of a variety of individuals. The results are encouraging as they know the status of their ability to improve overall physical health and mental well-being which may be considered as a prime importance of basketball players.

It was also observed from the review of literature that there is no research studies related to present study in analyzing selected variables which are contributed to the performance. This inference has motivated the researcher to undertake this study.
The review of literature helped the researcher from the methodological point of view too. It was learnt that most of the research studies cited in this chapter on content analysis and experimental design as the appropriate methods for finding out the lapses and remediation.