Chapter II

REVIEW OF RELATED LITERATURE

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

Anthropometry

*Height and body mass*

Montgomery (2006) examined the size, strength, and aerobic fitness of players from a professional hockey team. Beginning in 1917, data on body size were obtained from historical records of the Montreal Canadians. Body composition, strength, and VO$_{2}$max were obtained through physiological testing of Canadian players between 1981 and 2003. Compared with players in the 1920s and 1930s, current players were an average of 17 kg heavier and 10 cm taller, with BMI increased by 2.3 kg/m$^2$. The gain in BMI was not attributed to added fat mass, since percent body fat remained unchanged over the past 22 years. From 1992 to 2003, upper body strength was assessed using a bench press test.
Predicted 1 repetition maximum (1 RM) for the 17- to 19-year-old group was 107.0 kg with the highest values attained by the 25- to 29-year-old age group (128.1 kg). Gains in body mass were associated with an increase in upper body strength. VO\textsubscript{2}\text{max} was measured annually on a treadmill between 1992 and 2003 with annual mean values ranging between 54.6 and 59.2 mL x (kg x min)(-1). Compared with values from players in the early 1980s, VO\textsubscript{2}\text{max} has increased with the improvements independent of body mass; however, given the variability in the data, they are hesitant to infer that VO\textsubscript{2}\text{max} has increased significantly during the 1990s.

**Groger, Oettl and Tusker (2001)** in 1996 selected 89 German male national junior hockey players were examined in respect to weight, height, age and body mass of the lower extremities. The average age was 16.8 +/- 1.4 years with an average height of 179.6 +/- 6.3 cm and weight of 73.9 +/- 8.9 kg. The Rohrer-index was 1.27 +/- 0.1. In a biomechanic test set up characteristic values of strength were determined. By position, defence men were as tall as forwards but heavier. Players in the age of 15 to 17 years had a higher mean relative maximum force in leg-extension than players in the age of 18 to 19 years. Forwards had better relative explosive force in leg-extension but a higher force deficit in knee flexion and extension. At the World Championship 1995/96 in Alberta German national junior players, seventh ranked, had the lowest mean Rohrer-index and were the tallest one, but had the mean lowest weight of all teams.
Durandt, et al., (2007) compared the physical attributes of elite South African hockey and soccer players. To achieve the purpose they selected elite hockey players (N=39: 22±3 years; mean ± standard deviation) and soccer players (N=37; 24±4 years) completed a set of physical tests including a 10 m and 40 m sprint test, a repeated sprint test (sprint fatigue resistance), a 1RM bench press and a push-up test. The results showed that there were no differences in the 10 m (1.8±0.1 s both groups) and 40 m (5.4±0.2 s v. 5.3±0.2 s; hockey v. soccer) sprint times and distance run in the repeated sprint test (754±14 m v. 734±51 m). The hockey players were stronger (82±16 v. 65±13 kg) and did more push-ups (49±12 v. 38±10 push-ups) than the soccer players. It was concluded that acceptable to use the same type of sport-specific tests to measure sprint capacity and sprint fatigue resistance for hockey and soccer players. However, it was questionable whether the normative data derived for upper body strength for soccer players are relevant for hockey players, and vice versa.

Gabbetta, Kelly, Ralph, et al., (2009) stated that several studies have documented the physiological and anthropometric characteristics of senior rugby league players, investigations of the physical qualities of junior rugby league players are limited. The purpose of their study was to investigate the physical qualities of junior rugby league players competing at the elite and sub-elite level, and determine if pre-season fitness measures were significantly different for the players selected to play in the first game of the season (i.e. starters) compared to the players not selected (i.e. non-starters). Thirty-six junior sub-elite and 28 junior elite rugby league players participated in this study. All sub-elite players were
registered with the same junior recreational rugby league club, while elite players were members of a National Rugby League club junior development program. Subjects underwent measurements of anthropometry (height, body mass, and sum of seven skinfolds), speed (10 m, 20 m, and 40m 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. Elite players had better developed speed, change of direction speed, vertical jump, and maximal aerobic power than sub-elite players. Elite starters were taller and heavier than non-starters, while sub-elite starters were taller and had greater change of direction speed than non-starters. A high estimated maximal aerobic power was a common discriminator between starters and non-starters for both elite and sub-elite competitors. From their findings they demonstrated that some physical qualities can discriminate starters and non-starters in elite and sub-elite junior rugby league teams.

Abdelkrim, et al., (2010) in their study compared the physical attributes of elite men's basketball players according to age and specific individual positional roles. Forty-five players from 3 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. Under-
18 players were significantly ($p < 0.05$) shorter and lighter than both Senior and Under-20 players but showed higher ($p < 0.05$) percentage body fat. Under-20 and Senior players were faster and had better explosive-power and agility ($p < 0.05$) performances than Under-18 players. Bench press and squat 1RM were higher in Senior players ($p < 0.05$) compared with the other groups. There were significant differences in the Yo-Yo IR1 performance among groups ($Senior > Under-20 > Under-18, p < 0.05$). Centers and power forwards were the tallest and the heaviest ($p < 0.05$). The Yo-Yo IR1 performance was higher ($p < 0.01$) in point guards than in centers. Point guards showed also better agility and 5- and 10-m performances. Power forwards and centers were stronger than the rest of players' positions in the bench press 1RM ($p < 0.01$). 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. Strength and conditioning coaches should use Yo-Yo IR1 to assess specific endurance in players of different age and positional role.

**Body Composition**

*Percent body fat and lean body mass*

Polat, et al., (2011) examined the anthropometric values and the somatotypes of male children from different branches in physical education lessons and regular movement training. To achieve their purpose they selected two hundred and eighteen volunteer subjects at the age of 16, namely, 68 soccer
players, 89 persons practising fitness and 70 sedentary have participated in the study. In the research, sitting height, crawl length, body width parameters, body environment and somatotypic parameters of the subjects are measured. In this work, the highest humeral width value is achieved by the soccer group, where it is found to be no different from the fitness group ($P > 0.05$) and to be significantly higher than the sedentary group ($P < 0.05$). When femur width parameter is examined, it is determined that the soccer group is higher than the other two groups and that the fitness group is significantly higher than the sedentary group. In the study, while the highest endomorph value is obtained from sedentary group, it is found to be significantly higher than the other two groups ($P < 0.05$). While the highest mesomorph value is achieved from soccer group and the lowest value is achieved from sedentary group, it is determined that each of these three groups is significantly different from one another ($P < 0.05$). While the highest ectomorph value is achieved from fitness group ($P < 0.05$), it was found to be significantly higher than the other two groups ($P < 0.05$). It was concluded that the soccer players have more optimal dimension, environment and somatotypical structure when compared to those practising fitness and the sedentary group ($P < 0.05$).

Bale, et al., (1992) observed the cross-sectional nature of the effect of age, height, and body mass on motor performance during adolescence (13-18 years), 103 boy and 65 girl athletes were measured for motor performance and anthropometric variables. Motor performances included tests of strength, muscular endurance, flexibility, aerobic capacity, anaerobic power, speed, and
agility. Anthropometric determinations included height, body mass, lean body mass, %fat, and somatotype. Boys were significantly different from girls in all measurements except endomorphy, while girls were significantly superior to boys only in flexibility. Physical maturation, as reflected by height and body mass, was a major contributor to increases in motor performance. Somatotype did not differ greatly across the age groups. Boys were significantly more mesomorphic than girls, while girls were significantly more ectomorphic than boys. Higher %fat and more endomorphy were significantly related to poorer performance for relative aerobic capacity, 40-yd dash, and agility in boys but only for upper body muscular endurance in girls. Mesomorphy had higher relationships with performance variables among boys than among girls. Growth would appear to contribute significantly to enhanced motor performance with age, and its effect may be different in boys than in girls.

Scott (1991) established a data base of physical norms for elite male field hockey players. Direct measurements were made on eight parameters and a further three derived variables were calculated. With a stature of 176.3 cm and mass of 75.2 kg the hockey players were identified as ecto-mesomorphic. The lean build of the subjects was evident with a fairly low percentage body fat (11.1%) and a relatively high RPI of 41.77. Functional arm length did not appear to have any correlation with hockey playing ability. However, grip strength, in both right (54.0 kg) and left (53.1 kg) measures was above that of norms for male adults and there was no significant difference between left and right grip strength.
The players appeared to have good got leg strength (stand long jump mean 2.3 m) with very little variability amongst the players. On the other hand flexibility (sit and reach mean 9.7) was poor and results indicated a wide range of variability in the sample group tested.

Reilly and Borrie, (1992) stated that field hockey is a sport with a long history that has undergone quite rapid and radical change within the past decade. The advent of the synthetic playing surface has changed the technical, tactical and physiological requirements of the game at all levels, but in particular at the elite level. In order to cope with the technical evolution within the game, the hockey player has also had to develop physiologically to meet the physical standards required at elite levels. Analysis of the physiological cost and energy expenditure of playing hockey has placed it in the category of 'heavy exercise', with reported VO2 values during a game of 2.26 L/min. Energy expenditure has been estimated to range from 36 to 50 kJ/min. Physiological profiling of female hockey players has shown that somatotype tends towards 3.5/4.0/2.5. Figures for percentage body fat in female players range from 16 to 26%. Anaerobic power output has been shown to compare favourably with other groups of sportswomen and has also been shown to be a discriminating factor between elite and county level female players. Aerobic power amongst female players has been shown to range from 45 to 59 ml/kg/min. The reported somatotypes of male hockey players have shown considerable variation but there seems to be a trend away from ectomorphy towards mesomorphy. An aerobic power output in male players has been shown
to be the same as that of soccer players and better than other sports, e.g. basketball and also higher than reference norms. The range of aerobic power reported in the literature is 48 to 65 ml/kg/min and it would appear that an aerobic power in excess of 60 ml/kg/min is required for elite level play. The physical strain of hockey play has been shown to be considerable, in particular with respect to spinal shrinkage. There is a greater injury risk inherent in playing on synthetic surfaces than on grass.

Spencer, et al., (2004) stated that limited information exists about the movement patterns of field-hockey players, especially during elite competition. Time-motion analysis was used to document the movement patterns during an international field-hockey game. In addition, the movement patterns of repeated-sprint activity were investigated, as repeated-sprint ability is considered to be an important fitness component of team-sport performance. Fourteen members of the Australian men's field-hockey team (age 26 +/- 3 years, body mass 76.7 +/- 5.6 kg, VO2max 57.9 +/- 3.6 ml.kg(-1).min(-1); mean +/- s) were filmed during an international game and their movement patterns were analysed. The majority of the total player game time was spent in the low-intensity motions of walking, jogging and standing (46.5 +/- 8.1, 40.5 +/- 7.0 and 7.4 +/- 0.9%, respectively). In comparison, the proportions of time spent in striding and sprinting were 4.1 +/- 1.1 and 1.5 +/- 0.6%, respectively. Their criteria for 'repeated-sprint' activity (defined as a minimum of three sprints, with mean recovery duration between sprints of less than 21 s) was met on 17 occasions during the game (total for all players),
with a mean 4+/1 sprints per bout. On average, 95% of the recovery during the repeated-sprint bouts was of an active nature. Their results suggested that the motion activities of an elite field-hockey competition are similar to those of elite soccer, rugby and Australian Rules football. In addition, the investigation of repeated-sprint activity during competition has provided additional information about the unique physiological demands of elite field-hockey performance.

**Somatotype**

Over the course of the past century, it has become increasingly difficult to find athletes of the size and shape required to compete successfully at the highest level. Sport is Darwinian, in that only, the 'fittest' reach the highest level of participation. Not every physical characteristic could be expected to play a role in this selection process, but two that are important and for which substantial data assemblies exist, are height and mass. According to Norton and Olds, (2001) measurements of elite athlete sizes were obtained from a variety of sources as far back as records allowed. They charted the shift in these anthropometric characteristics of elite sportspeople over time, against a backdrop of secular changes in the general population. Athletes in many sports have been getting taller and more massive over time; the rates of rise outstripping those of the secular trend. In open-ended sports, more massive players have an advantage. Larger players average longer careers and obtain greater financial rewards. In some sports it is equally difficult to find athletes small enough to compete. In contrast, there are sports that demand a narrow range of morphological characteristics. In
these sports the size of the most successful athletes over the century has remained constant, despite the drift in the population characteristics from which they are drawn. A number of social factors both drive and are driven by the search for athletes of increasingly rare morphology. These include globalisation and international recruitment, greater financial and social incentives, and the use of special training methods and artificial growth stimuli. In many sports the demand for a specific range in body size reinforces the need to adopt questionable and illegal behaviours to reach the required size and shape to compete at the top level. Future scenarios also include 'gene-farming' through assortative mating and athlete gamete banks.

Heath and Carter, (1967) come up with a new and improved somatotype method with universal application to both sexes, for all ages and which is reproducible, is justified, validated and described. Evidence is presented for extension of previous component rating scales. Data on 844 male and female subjects from selected samples were used to develop and validate anthropometric scales for estimating the Health component ratings. The definitions and rating procedures for the new somatotype method are presented, with descriptions of the anthropometric somatotype and the combined photoscopic and anthropometric somatotype.

Somatotypes of athletes in different sports

Rienzi, Reilly and Malkin, (1999) evaluated the anthropometric and match performance profiles of international Rugby Sevens players and explore
correlations between anthropometric characteristics and work-rates in matches. The data was collected from players participating in the 1996 International Rugby Sevens tournament in Uruguay. Among thirty male players were selected. They measured work-rate analysis during matches (n = 30) and a comprehensive anthropometry profile of 27 of the 30 players. The results showed that forwards had more mass (whole-body, adipose tissue, muscle) than backs, jogged more frequently and paused more often. High intensity activity was negatively correlated with muscle mass and with mesomorphy. They concluded that anthropometric features are related to components of match play in Rugby Sevens but do not necessarily determine whether a game is won or lost.

Gualdi-Russo and Zaccagni, (2001) in their study examined the importance of the somatometric components of elite male and female volleyball players in relation to their different game roles and levels of performance. To achieve their purpose they selected two hundred and thirty-four male athletes (aged 24.7+/-4.4 years) and 244 female athletes (aged 23.1+/-4.4 years) from the Italian A1 and A2 volleyball leagues underwent anthropometric measurements during the 1992-1993 and 1993-1994 seasons. Somatotypes were estimated with the Heath-Carter method. The results showed marked sexual dimorphism in somatotype was observed in the total sample. The average somatotype for men was 2.2-4.2-3.2 (SD 0.7-0.9-0.9), and for women it was 3.0-3.3-2.9 (SD 0.8-1.0-0.9). The somatotype was significantly different in players at different levels of performance (A1 vs A2 leagues), as it follows: 2.1-4.1-3.3 (SD 0.6-0.8-0.7) vs 2.3-
4.3-3.0 (SD 0.7-1.0-0.8) in males; 2.9-3.1-3.0 (SD 0.8-1.0-0.9) vs 3.1-3.5-2.7 (SD 0.8-0.9-0.8) in females. The somatotype was also significantly different in players in different roles. In male sex the mean somatotypes for setters were 2.4-4.5-2.8 (SD 0.7-0.9-0.8), for centres they were 2.0-4.0-3.5 (SD 0.6-1.0-0.8), for spikers they were 2.2-4.3-3.0 (SD 0.6-0.9-0.7), for opposites they were 2.2-4.3-3.1 (SD 0.6-0.9-0.8). In female sex the mean somatotypes for setters were 3.1-3.6-2.5 (SD 0.8-1.0-1.0), for centres they were 2.8-3.1-3.1 (SD 0.8-0.9-0.7), for spikers they were 3.0-3.5-2.8 (SD 0.9-1.0-0.9) and for opposites they were 3.0-3.2-3.0 (SD 0.7-0.9-0.8). They concluded that the physique of athletes in the A1 league is characterized by higher ectomorphy and lower endomorphy and mesomorphy. There was also a slight tendency of male players to a greater homogeneity in somatotype within the group at the maximum level of performance. Moreover, somatotype differs in relation to game role in volleyball players of both sexes: the mesomorphic component is maximal in setters, while the ectomorphic component was maximal in centres.

Orvanova (1990) in his paper consolidated the reviews published on the body shape of weight lifters. The differences between the somatotype ratings of weight lifters studied using the Sheldon and the Heath-Carter methods, and the differences between performance levels and age groups of weight lifters are discussed. The differences in mean somatoplots among the weight lifters studied as a whole group, weight lifters divided into two, three or four groups according to body weight, and weight lifters considered according to the official weight
classes, are assessed. Weight lifters in the lighter weight classes are found to be ectomorphic or balanced mesomorphs, while those in the heavier weight classes tend to be endomorphic mesomorphs. Ectomorphy decreases, whereas mesomorphy and endomorphy increase with weight class. When three age groups of weight lifters were compared within each weight class, the same pattern of differences between ages occurs. The younger lifters in each weight class have higher endomorphy and lower mesomorphy than the senior lifters. Ectomorphy is higher in the younger lifters below the weight class of 82.5 kg. Since significant differences in all three somatotype components between 10 weight classes of weight lifters and also within three age groups were noted, it will be necessary in future studies to consider the somatotypes of weight lifters according to the official weight classes.

Charzewski, (1991) studied the somatotypes of 228 European elite wrestlers, both free and Graeco-Roman styles, were studied. The data were collected during the European wrestling championships and processed according to Sheldon, as modified by heath and carter, in order to assess the endo, meso, ectomorphic parameters. The somatotypes of wrestlers were marked differentiated due to a wide range of weight categories. In all those categories, however, the predominating somatotype was mesomorphy which was particularly expressed in highest weight categories. Mesomorphy was also the principle factor responsible for the relative uniformity of wrestlers somatotype. Moreover, highest somatotype
similarity was observed among those wrestlers who scored highest at the championships.

Claessens, et al., (1991) measured the anthropometric data of outstanding gymnasts were gathered on the occasion of the 24th World Championship Artistic Gymnastics, held at Rotterdam, The Netherlands, in October 1987. In total 165 males and 201 females were investigated, constituting 84% of the total number of participants. The data of these gymnasts were descriptively compared with both reference data and data reported in previous studies on gymnasts competing at international events. Also, based on the data obtained, ‘gymnastic-specific’ anthropometric reference values (i.e. profile charts), were established for both male and female gymnasts. Finally, the maturational characteristics (skeletal age and menarche) of the ‘Rotterdam’ female gymnasts were described.

Leake and Carter (1991) studied triathletes body composition and somatotype. Sixteen (16) trained female triathletes were selected their age ranged between 18.8–32.8 years were measured. All of the subjects were engaged in a competitive training programme and participated in the same triathlon. Anthropometric variables included height, mass, selected diameters, girths and skinfolds, and a Heath-Carter anthropometric somatotype. Body composition was determined by hydrostatic weighing procedures and skinfold patterns. Comparisons were made with Olympic swimmers and runners. The triathletes had a mean body mass of 55.2 kg and a mean height of 162.1 cm. When compared to swimmers, the triathletes were somewhat shorter and significantly ($P < 0.005$)
older. On most other measures, including a balanced mesomorph somatotype of
3.1–4.3–2.6, they were similar to swimmers. The group of triathletes were
generally heavier, less lean, more mesomorphic and less ectomorphic than elite
runners. Reported body densities from other studies indicated little difference
between the triathletes and other groups. Skinfold patterns were similar in shape
for all groups, but the runners had smaller values, at all sites, than either
swimmers or triathletes. Because of lack of information on cyclists, adequate
comparisons were not possible. Regression analysis indicated that training
parameters were more important than anthropometric measures in the prediction
of performance. It was concluded that the group of triathletes were closer, with
respect to both body composition and somatotype, to swimmers than to runners.

Gualdi-Russo and Graziani (1993) analysed somatotypes of 1593 young
Italian sport participants (717 males and 876 females) were described and
analyzed. The average somatotype for sport participants was 2.7-4.7-2.7 for males
and 3.6-3.7-2.8 for females. The predominance of mesomorphy on the other two
components was found in all sport-groups examined. This was particularly
evident in males for gymnasts and rowers and in females for martial arts
competitors. As for sexual dimorphism, females were endo-mesomorphs, while
males were balanced mesomorphs. Somatotypes show statistically significant
changes with the level of performance in some sport-groups with an increase in
the mesomorphic component (in ballgames and martial arts) and in the
endomorphic component (*in swimming*). Comparisons with other sport-groups from literature were greatly limited by several genetic and environmental factors.

**Hawes and Sovak (1994)** identified the concept of a morphological prototype in relation to the development of athletes is examined from the standpoint of the kinanthropometric techniques available to the sport scientist. Examples of the utility of the morphological prototype in the context of modern-day sport are provided in a variety of winter and summer sports. Somatotypes drawn from competitors at the 1988 Olympic and 1991 World Junior Speed Skating Championships are presented representing the somatotypic prototype. Statement of the prototype in variables that are both discrete and sensitive to change over the short term is considered to be more appropriate for evaluating the progress of young athletes. Examples drawn from speed skating, figure skating, swimming and synchronized swimming are used to illustrate changes and differences in muscle mass, skinfold corrected muscle diameters, bone mass and sum of skinfolds. The concept of establishing an individual ideal prototype through optimizing morphological variables is introduced.

The aim of **Casagrande and Viviani,** (1993) was to collect lacking first-hand data on Italian rugby players. The Heath/Carter anthropometric somatotype method was applied to 28 "A" League performers (RP) aged 25 +/- 3.9 years of age. Their somatotypes and dimensions were compared with those found in previous studies on athletes involved in the same sporting activity, with data collected on 25 "sedentary" young Italians, and with Bailey *et al.*'s study on
Canadians (1982). On average, the RP group resulted as being endomorphic mesomorphs (3.1 +/- 1.1 - 5.6 +/- 1.3 - 1.4 +/- 1.1), a result that is congruent with international data. They differed significantly from the balanced mesomorph CG (2.3 +/- 1.0 - 4.5 +/- 1.2 - 2.5 +/- 1.4) for all the measurements taken, apart from bi-epicondylar width. The peculiar somatotype scores found are congruent with the needs of rugby, an aerobic-anaerobic discipline which requires performers with great muscular power associated with a capacity to furnish energy, mainly through the anaerobic metabolism.

The aim of Viviani (1994) was to determine the somatotype of average basketball players (BP) and to compare them with the values found in relevant literature. Thirty-eight Italian members of "B" and "C" BP league teams were measured according to the Health/Carter anthropometric somatotype method. Since their group was, on average, made up of mesomorphic-ectomorphs (2.2-3.2-3.8), it appeared to be quite well suited to the sporting activity undertaken. However, the comparison carried out for the anthropometric variables and the somatotype scores found for higher level athletes, show that their physique lacks some of the characteristics needed to excel.

Carter, et al., (2005) compared the somatotype and size of elite female basketball players in terms of playing position and team performance. Anthropometry and somatotype data were collected on 168 players from 14 countries before the Women's World Basketball Championship, Australia, 1994. There were 64 guards (mean±s: age 25.4±3.3 years, height 1.72±0.06 m, mass
66.1±6.2 kg, somatotype=2.9–3.9–2.6), 57 forwards (age 25.2±3.8 years, height 1.81±0.06 m, mass 73.3±5.9 kg, somatotype=2.8–3.5–3.2) and 47 centres (age 24.1±3.1 years, height 1.90±0.06 m, mass 82.6±8.2 kg, somatotype=3.2–3.1–3.4). Mean somatotypes by position were significantly different (F=7.73, P <0.01). Guards had greater mesomorphy than centres and less ectomorphy than forwards and centres. When discriminant function analysis was applied to endomorphy, mesomorphy, ectomorphy, age, height and mass, only height, mass and ectomorphy entered (Wilks’ λ=0.351, F=31.40, P <0.000), 70% of the variance was accounted for, and 72% of players were correctly classified. In the four top versus four bottom teams, guards were taller and more ectomorphic, forwards were taller, with lower mesomorphy and higher ectomorphy, and centres did not differ. Thus, there are some differences in somatotypes by position and team placing, but the combination of height, mass and ectomorphy provide the best differentiation by position.

Bayios, et al., (2006) approached their problems in three folds as: a) to determine the anthropometric profile, body composition and somatotype of elite Greek female basketball (B), volleyball (V) and handball (H) players, b) to compare the mean scores among sports and c) to detect possible differences in relation to competition level. To fulfill the purpose they selected 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. The results showed V athletes were the tallest (P<0.001) among the three groups of athletes, had the lowest values of body fat (P<0.001) and their somatotype was characterized as balanced endomorph (3.4-2.7-2.9). B athletes were taller (P<0.01) and leaner (P<0.001) than H players, with a somatotype characterized as mesomorph-endomorph (3.7-3.2-2.4). H athletes were the shortest of all (P<0.01), had the highest percentage of body fat (P<0.001) and their somatotype was mesomorph-endomorph (4.2-4.7-1.8). In comparison with their A2 counterparts the A1 division players were taller (P<0.001) and heavier (P<0.01), but at the same time leaner (P<0.001), and exhibited higher homogeneity in somatotype characteristics (P<0.05). The authors 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. More data are certainly needed to define the anthropometric profile of B, V and H female athletes internationally.

Neni and Santosa, (2007) stated that there is a considerable corpus of evidence indicating that athletes succeeding in certain sports have distinctive body shapes that differ according to the demands of the type of sports and competitive level. Their aim was to determine the specific morphological characteristics of young male athletes compared with non-athlete students in Indonesia. Anthropometric measurements of 19 badminton players, 96 soccer players, 74
volleyball players, and 51 non-athlete undergraduate students, aged 16 to 28, were obtained in 1994 and 1995. Stature, body weight, bicondylar breadths of the humerus and femur, calf and upper arm circumferences, and skinfolds (at triceps, subscapula, calf, and supraspine) were measured for each subject. Heath-Carter somatotypes were determined in all the subjects. The results of the ANOVA of the body measurements showed that the three groups of athletes and the non-athlete students were heterogeneous: the badminton players were shorter and lighter with greater skinfold values among the athlete groups; the soccer players were relatively shorter and with smaller skinfold values and greater arm and leg girths; and the volleyball players were taller and heavier with smaller elbow and knee breadths and very small skinfold values. The non-athlete students were characterized by greater arm girth, elbow breadths, knee breadths, and back and leg skinfolds. In mean somatotype category, the badminton players were ‘central’ (3.3-3.7-3.7), the soccer players were ‘balanced mesomorph’ (2.7-4.9-3.0), the volleyball players were ‘mesomorph-ectomorph’ (2.4-3.5-3.7), and the non-athlete students were ‘ectomorphic mesomorph’ (2.7-5.2-3.8). Comparisons of international scope with each of the different sports showed that the Indonesian players were extremely short and light.

Malousaris, et al., (2008) in their work they studied the morphological characteristics of competitive female volleyball players. For that purpose, body weight and height, breadths and girths as well as skinfold thickness at various body sites were assessed in 163 elite female volleyball players (age: 23.8+-4.7
years, years of playing: 11.5+/-4.2, hours of training per week: 11.9+/-2.9, means+/-S.D.). Seventy-nine of these players were from the A1 division and the rest from the A2 division of the Greek National League. Two-way ANOVA was used to compare the differences in these characteristics between competition level and playing position. Body height ranged from 161cm to 194cm, and the mean value (177.1+/-6.5cm) was not inferior to that of international players of similar calibre. Adiposity of these players (sum of 5 skinfolds: 51.8+/-10.2mm, percent body fat: 23.4+/-2.8) was higher than that reported in other studies in which, however, different methodology was used. Volleyball athletes of this study were mainly balanced endomorphs (3.4-2.7-2.9). The A1 division players were taller and slightly leaner with greater fat-free mass than their A2 counterparts. Significant differences were found among athletes of different playing positions which are interpreted by their varying roles and physical demands during a volleyball game. The volleyball players who play as opposites were the only subgroup of players differing between divisions; the A2 opposites had more body fat than A1 opposites. These data could be added in the international literature related to the anthropometric characteristics of competitive female volleyball players.

Dey, Khanna, and Batrat (1993) selected twenty-five national kabaddi players (Asiad gold medalists 1990), mean age 27.91 years, who attended a national camp at the Sports Authority of India, Bangalore before the Beijing Asian Games in 1990, were investigated for their physical characteristics, body fat, lean body mass (LBM) and somatotype. The physiological characteristics
assessed included back strength, maximum oxygen uptake capacity and anaerobic capacity (oxygen debt) and related cardiorespiratory parameters (oxygen pulse, breathing equivalent, maximum pulmonary ventilation, maximum heart rate). Body fat was calculated from skinfold thicknesses taken at four different sites, using Harpenden skinfold calipers. An exercise test (graded protocol) was performed on a bicycle ergometer (ER-900) using a computerized EOS Sprint (Jaeger, West Germany). The mean(s.d.) percentage body fat (17.56(3.48)) of kabaddi players was found to be higher than normal sedentary people. Their physique was found to be endomorphic mesomorph (3.8-5.2-1.7). Mean(s.d.) back strength, maximum oxygen uptake capacity (Vo2m.) and oxygen debt were found to be 162.6(18.08) kg, 42.6(4.91) ml kg⁻¹ min⁻¹ and 5.02(1.29) litre respectively. Physical characteristics, percentage body fat, somatotype, maximum oxygen uptake capacity and anaerobic capacity (oxygen debt) and other cardiorespiratory parameters were compared with other national counterparts. The data are comparable with data for judo, wrestling and weightlifting. Since no such study has been conducted on international counterparts, these data could not be compared. These data may act as a guideline in the selection of future kabaddi players and to attain the physiological status comparable to the present gold medalists.

Bandyopadhyay (2007) selected 50 sedentary males and 128 sportspersons (volleyball=82, soccer=46) of 20–24 years were selected from West Bengal, India, to evaluate and compare their anthropometry and body composition. Skinfolds, girth measurements, body fat percentage (%fat), and
endomorphy were significantly higher among sedentary individuals, but lean body mass (LBM) and mesomorphy were significantly ($p<0.001$) higher among the sportspersons. Soccer and volleyball players were found to be ectomorphic mesomorph, whereas sedentary subjects were endomorphic mesomorph. The soccer and volleyball players had higher %fat with lower body height and body mass than their overseas counterparts. %fat exhibited a significant correlation with body mass index (BMI) and thus prediction equations for %fat from BMI were computed in each group. The data will serve as a reference standard for the anthropometry and body composition of Indian soccer and volleyball players and the prediction norms for %fat will help to provide a first-hand impression of body composition in the studied population.

Abraham (2010) in his study intended to analyze the anthropometry and body composition associated with performance of university level male track and field athletes of South India. The study was conducted on 93 track and field athletes from South India, comprised of 22 sprinters (100 & 200 mts), mean age 19.5 years, height 172.1 cm and weight 68.2 kg, 20 middle distance runners (800 & 1500 mts), mean age 19 yrs, height 166.8 cm and weight 62.5 kg, 16 long distance runners (5000 & 10000 mts), mean age 18.7 years, height 167.2 cm and weight 62.1 kg, 20 throwers, (shot, discus & hammer throw), mean age 19 years, height 170.8 cm and weight 72.6 kg and jumpers (High, long & triple jump), mean age 18.3 years, height 169.9 cm and weight 64.1 kg. Besides height and weight, six skin folds (triceps, chest, subscapular, abdomen, suprailiac & calf), two bicondylar breadths (humerus & femur) and two girths (biceps & calf) were
measured. Somatotype evaluations were made according to Carter and Heath (1990) method. BMI was calculated as body mass divided by square of height (kg/m2). The somatochart indicated that sprinters and middle distance runners are ectomorphic mesomorphs, long distance runners are mesomorph ectomorphs while throwers are endomorphic mesomorphs. The jumpers fell into the somatotype category of balanced mesomorphs. Among all groups body fat percent is lowest in sprinters (6.23±0.83%) and highest in throwers (7.38±0.85%). This was reflected in their endomorphic components which is lowest in sprinters (2.53±0.45) and highest in throwers (3.39±0.65). Ectomorphic component is highly marked in long distance runners (3.56±0.65) while mesomophy was highest in sprinters (4.31±0.91). Throwers have significantly higher values of skin folds than other groups. Compared to their overseas counterparts, the athletes of both track and field events in the study exhibited greater endomorphic values. The data will serve as a reference standard for the anthropometry and body composition of south Indian track and field athletes.

Siders, (1993) tried to identify the relationships between sprint swimming performance and estimates of body composition and somatotype components in competitive collegiate swimmers. Forty-three women and 31 men underwent anthropometric and hydrodensitometric measurements at the beginning of a competitive season. There were significant partial correlations (swim stroke was partialed out) between swimming performance (time in a competitive 100-yard swim of each swimmer's major competitive stroke) and height (-0.466, p < 0.01), the mesomorphic (0.404, p < 0.01) and ectomorphic (-0.398, p < 0.01)
components of somatotype, percent body fat (0.351, p < 0.05), and fat-free weight (-0.332, p < 0.05) among the women, but no significant correlations among the men. Twenty-three of the women and 21 of the men were also measured and timed at the end of the competitive season. Again, there were significant (p < 0.01) partial correlations (season and stroke were partialed out) between swimming performance and height (-0.766), fat-free weight (-0.657), body weight (-0.437), and the ectomorphic (-0.441) and mesomorphic (0.392, p < 0.01) components of somatotype in women, but no significant correlations among the men. These findings indicated that measurements of body composition and somatotype may be predictors of swimming performance in women but not in men.

Sullivan, et al., (1994) determined the anthropometric characteristics of skilled adolescent pole vaulters and to examine the strength of anthropometric and physical performance variables in predicting vaulting performance (N = 87; age group range 13-18 years). The vaulting height of the subjects ranged from 1.98 to 4.72m (mean 3.58 +/- s.d. 0.536m). The vaulters were classified as ectomorphic mesomorphs with an average somatotype of 1.6-4.2-3.5 (s.d. +/- 0.38-0.94-1.00). One way analysis of variance showed that while measures of stature, physical performance and vault performance significantly increased (p < 0.05) across age groups, somatotype and sum of skinfolds remained stable. Stepwise regression analysis showed the best predictor of vaulting performance was hand grip height (R2 = 0.78, p < 0.05). Correlation analysis showed that grip height was strongly correlated to vault height (r = 0.88), age (r = 0.72), body mass (r = 0.71), standing
long jump \((r = 0.69)\), running speed \((r = 0.69)\), biceps girth \((r = 0.66)\), standing height \((0.65)\), calf girth \((0.61)\) and pull-ups \((r = 0.44)\). It was concluded that the somatotype of skilled young pole vaulters is similar to that of junior Olympic and adult Olympic vaulters, and that this somatotype is a selective factor for this event as early as thirteen years of age. Proficiency in pole vaulting is best predicted by grip height, which is strongly correlated to stature and simple field measures of leg speed and power, and upper body muscular endurance. These findings may be applied to the selection and training of young pole vaulters.

Sanchez-Munoz, Sanz, and Zabala (2007) compared the anthropometric data, body composition and somatotype of the first 12 elite junior tennis players on the ranking with the lower ranked players, and to establish an anthropometric profile chart for elite junior tennis players. The purpose was attained by selecting 123 (57 males and 66 females) elite junior tennis players participated in this study. The athletes were divided into two groups, the first 12 and the lower ranked players, according to gender. A total of 17 anthropometric variables were recorded of each subject. The result of the study showed there was no significant differences in height and weight between the first 12 and the lower ranked boys, while the first 12 girls were significantly taller than the lower ranked girls \((p = 0.009)\). Significant differences were found for humeral and femoral breadths between the first 12 and the lower ranked girls \((p = 0.000; \ p = 0.004\), respectively\). The mean (SD) somatotype of elite male junior tennis players could be defined as ectomesomorphic \((2.4 (0.7), 5.2 (0.8), 2.9 (0.7))\) and the mean (SD)
somatotype of elite female junior tennis players evaluated could be defined as
endomesomorphic (3.8 (0.9), 4.6 (1.0), 2.4 (1.0)). No significant differences were
found in somatotype components between the first 12 and the lower ranked
players of both genders. It was concluded that when comparing the first 12 and
the lower ranked elite junior tennis players of both genders, no significant
differences were observed in any measured item for the boys. By contrast,
significant differences were observed in height and humeral and femoral breadths
between the first 12 and the lower ranked girls, whereby the first 12 were taller
and had wider humeral and femoral breadths than the lower ranked players. These
differences could influence the playing style of junior female players.

The main objectives of Munivrana, Pausic and Kondric (2011) research
were to determine the somatotype of the best young male Croatian table tennis
players using the Carter and Heath (1990) method and to establish whether the
subjects classified in three groups of physique, according to similarities in their
somatotype component values, differ in terms of their age, years of training, and
especially competitive success. The results revealed the predominance of the
mesomorphic somatotype component, which was evident and emphasized in
almost half the subjects. The ectomorphic somatotype component was also
significant since it was established as a dominant component of more than one-
third of the subjects while, as expected, the least dominant component is the
endomorphic component. The results of an analysis of variance revealed that the
subjects in each group dominated by a different somatotype component are the
same age and possess the same playing experience, and that the groups do not differ in their competitive success. It was thus possible to conclude that the somatotype of players at this age is not a crucial factor in achieving competitive success in table tennis. The predominance of a physique dominated by the mesomorphic and ectomorphic somatotype components only reveals the potential advantage of these body constitution types, one that increases the probability of success but is not a factor that directly influences the competitive success of young table tennis players.

**Zary, et al., (2010)** investigated the somatotype and dermatoglyphic profiles of players of three Brazilian national volleyball teams: adults, juvenile and infant-juvenile. To carry out the study they selected 38 male players included in the three national teams were observed. The subjects were submitted to an evaluation to identify the dermatoglyphic profile by means of fingerprints, following the protocol of Cummins and Midlo (1942). The digital impressions (DI) designs were used to determine the different patterns and the predominant types of digital form. The subjects were also submitted to an evaluation of the somatotype by the anthropometric method of Carter and Heath (1990). The result of the study showed that the infant-juvenile and the juvenile national Brazilian teams are classified on Class III of the Dermatoglyphic and Somato-Funtonal Index Classification; while the adult team is classified on Class IV of the same referential. The somatotype of the volleyball players in the study was similar to those described in the literature for other elite national volleyball teams. They
found a lower endomorphism in the juvenile team and a lower ectomorphism in the adult team.

**Rico-Sanz (1998)** summarized results from studies investigating the physical characteristics, daily energy expenditures, diets, and effects of nutritional supplements to the habitual diets of soccer players. The results showed that players fall within a wide range of stature and body weight, and they are classified as mesomorphs. The body fat of male players is about 10% of body weight, whereas the average for females is about 21%. Energy expenditure for males is about 4,000 kcal on training days and 3,800 kcal on match day, while energy intake reported in other studies is on the order of 3,700 kcal. Carbohydrate (CHO), fat, and protein intakes are about 53, 30, and 14% of energy intake, respectively, the remaining being from alcohol intake. There are indications that CHO supplements might be beneficial during soccer performance. However, more research is needed to clarify the importance of branched-chain amino acid and creatine supplementation in soccer.

**Keogh (1999)** performed a study to determine if anthropometric and fitness testing scores can be used to discriminate between players that were selected or not selected in an elite Under 18 Australian Rules Football side. A training squad of 40 Australian Rules Football players was assessed on a battery of standard anthropometric and fitness tests just prior to the selection of the 30 man player roster for the upcoming season. Results showed that the selected players were significantly (P<0.05) taller and had greater upper body strength than non-selected
players. A discriminant analysis was performed which predicted with an accuracy of 80% whether each player was successful or unsuccessful in gaining selection. That suggested that physical conditioning and anthropometric measurements do play an important part in determining selection in elite junior Australian Rules Football teams. However the discriminant function predicted non-selected players (90.9%) better than it predicted selected players (75.9%). Selected Under 18 players were found to be similar to the values reported for elite to sub-elite senior players on height, sit and reach, CMJ and perhaps aerobic fitness, but considerably less than the senior players on 3RM bench press and body mass.

**Reilly and Borrie, (1992)** stated that field hockey is a sport with a long history that has undergone quite rapid and radical change within the past decade. The advent of the synthetic playing surface has changed the technical, tactical and physiological requirements of the game at all levels, but in particular at the elite level. In order to cope with the technical evolution within the game, the hockey player has also had to develop physiologically to meet the physical standards required at elite levels. Analysis of the physiological cost and energy expenditure of playing hockey has placed it in the category of 'heavy exercise', with reported VO$_2$ values during a game of 2.26 L/min. Energy expenditure has been estimated to range from 36 to 50 kJ/min. Physiological profiling of female hockey players has shown that somatotype tends towards 3.5/4.0/2.5. Figures for percentage body fat in female players range from 16 to 26%. Anaerobic power output has been shown to compare favourably with other groups of sportswomen and has also
been shown to be a discriminating factor between elite and county level female players. Aerobic power amongst female players has been shown to range from 45 to 59 ml/kg/min. The reported somatotypes of male hockey players have shown considerable variation but there seems to be a trend away from ectomorphy towards mesomorphy. Anaerobic power output in male players has been shown to be the same as that of soccer players and better than other sports, e.g. basketball and also higher than reference norms. The range of aerobic power reported in the literature is 48 to 65 ml/kg/min and it would appear that an aerobic power in excess of 60 ml/kg/min is required for elite level play. The physical strain of hockey play has been shown to be considerable, in particular with respect to spinal shrinkage. There is a greater injury risk inherent in playing on synthetic surfaces than on grass.

Mathur, Toriola and Igbokwe (1985) evaluated somatotype ratings and percentage body fat of 131 elite Nigerian male athletes, average 24.2 years of age, and belonging to badminton (n = 18), basketball (n = 30), field hockey (n = 24), handball (n = 16), judo (n = 18), and soccer (n = 25) teams were determined. Basketball, handball and soccer players were taller and heavier, and had low percent fat values as compared with the other athletic groups. Judokas and hockey players were endomesomorphs. Other sports groups were predominantly ectomesomorphs.

Toriola, Salokun and Mathur (1985) took an effort to describe the physique associated with regular involvement in sports activity, the somatotypes
of a group of 51 elite male athletes comprising sprinters (n = 10), basketball (n = 12), soccer (n = 15), and field hockey (n = 14) players, and 11 male nonathletes were studied. The subjects’ physiques were assessed using the Heath-Carter anthropometric somatotype method. Analysis of variance and Newman-Keuls post hoc method were used to test for significant differences among the mean somatotype ratings of the groups. The findings indicated that the non-athletes (3.5) were significantly more endomorphic (P less than 0.05) than the soccer players (2.5) and sprinters (2.4). The sprinters (3.6) and basketball players (3.7) had markedly higher ectomorphic ratings (P less than 0.05) as compared with the hockey players (2.0). The mesomorphic component did not differentiate the groups. The differences observed among the groups which could be attributed to genetic and environmental influences reflect the variability in the morphological characteristics of athletes and non-athletes.

There is a lack of published data on the anthropometric and relative-age effect of elite youth field hockey players. Holway & Seara (2011) coined three folds of purpose as: (a) to establish the anthropometric characteristics of elite junior Argentine male field hockey players; (b) to look for differences in physique, years of playing and birth-date effect between the final players selected to make up the team and those who were not selected out of the original pre-selected sample; and (c) to establish whether there are any differences in proportional limb lengths between elite junior hockey players and a local reference sample. To achieve the purpose thirty five elite Argentine junior field
hockey players pre-selected to form the base of the national junior team for the 2005 Junior World Cup (Age 19.0 ± 1.0 years; weight 70.7 ± 5.4 kg; height 176.4 ± 6.4 cm). A full anthropometric battery including lengths, heights, breadths, girths, and skinfolds, plus number of years playing and date of birth. The result of the study showed no statistically significant differences were found in skeletal structural dimensions when compared to a reference sample, nor between finally selected and non-selected players in anthropometric dimensions, playing history ($P = .11$) and relative-age effect ($P = .11$). It was concluded that male field hockey is a sport with normal bone-structural requirements, and with a lack of birth-date effect in Argentina.

**The Physical Demands of Field Hockey**

* Aerobic and Anaerobic Endurance

According to **Reilly and Borrie, (1992)** field hockey is a sport with a long history that has undergone quite rapid and radical change within the past decade. The advent of the synthetic playing surface has changed the technical, tactical and physiological requirements of the game at all levels, but in particular at the elite level. In order to cope with the technical evolution within the game, the hockey player has also had to develop physiologically to meet the physical standards required at elite levels. Analysis of the physiological cost and energy expenditure of playing hockey has placed it in the category of 'heavy exercise', with reported VO2 values during a game of 2.26 L/min. Energy expenditure has been estimated to range from 36 to 50 kJ/min. Physiological profiling of female hockey players has shown that somatotype tends towards 3.5/4.0/2.5. Figures for percentage body
fat in female players range from 16 to 26%. Anaerobic power output has been shown to compare favourably with other groups of sportswomen and has also been shown to be a discriminating factor between elite and county level female players. Aerobic power amongst female players has been shown to range from 45 to 59 ml/kg/min. The reported somatotypes of male hockey players have shown considerable variation but there seems to be a trend away from ectomorphy towards mesomorphy. Anaerobic power output in male players has been shown to be the same as that of soccer players and better than other sports, e.g. basketball and also higher than reference norms. The range of aerobic power reported in the literature is 48 to 65 ml/kg/min and it would appear that an aerobic power in excess of 60 ml/kg/min is required for elite level play. The physical strain of hockey play has been shown to be considerable, in particular with respect to spinal shrinkage. There is a greater injury risk inherent in playing on synthetic surfaces than on grass.

To establish the energy cost of competitive field hockey Boyle, Mahoney, and Wallace, (1994) selected nine international hockey players wore a modified Sport Tester PE3000 telemetric heart rate monitor during match play and also completed a laboratory based incremental treadmill test to establish maximal oxygen uptake (VO\textsubscript{2}\text{max}). The heart rate data from competition were compared with heart rate and oxygen uptake data measured in the laboratory. Individual regression equations were established from these data to estimate the energy expenditure during competitive match-play. The mean heart rate during competition was 159 +/- 8 beats/min (mean +/- SD). The mean estimated oxygen
uptake during competition was 48.2 +/- 5.2 ml/kg/min which is commensurate with 78% of the group's mean maximal oxygen uptake of 61.8 +/- 1.8 ml/kg/min. The mean estimated energy expenditure throughout an entire match was 5.19 MJ and rates of energy expenditure ranged from 83 kJ/min for the centre midfield position to 61.1 kJ/min for the left corner forward position. The study has shown the feasibility of heart rate monitoring as a means of estimating energy expenditure in elite hockey. Competitive matches place a heavy demand on the aerobic system and require players to expend energy at relatively high levels.

Elferink-Gemser, et al., (2004) to determine the relationship between multidimensional performance characteristics and level of performance in talented youth field hockey players, elite youth players (n = 38, mean age 13.2 years, s = 1.26) were compared with sub-elite youth players (n = 88, mean age 14.2 years, s = 1.26) on anthropometric, physiological, technical, tactical and psychological characteristics. Multivariate analyses with performance level and gender as factors, and age as the covariate, showed that the elite youth players scored better than the sub-elite youth players on technical (dribble performance in a peak and repeated shuttle run), tactical (general tactics; tactics for possession and non-possession of the ball) and psychological variables (motivation) (P < 0.05). The most discriminating variables were tactics for possession of the ball, motivation and performance in a slalom dribble. Age discriminated between the two groups, indicating that the elite youth players were younger than the sub-elite players. In the guidance of young talented players to the top as well as in the
detection of talented players, more attention has to be paid to tactical qualities, motivation and specific technical skills.

Limited information exists about the movement patterns of field-hockey players, especially during elite competition. Time-motion analysis was used to document the movement patterns during an international field-hockey game. In addition, the movement patterns of repeated-sprint activity were investigated, as repeated-sprint ability is considered to be an important fitness component of team-sport performance. **Spencer, Bishop and Lawrence, (2004)** selected fourteen members of the Australian men's field-hockey team (*age 26 +/- 3 years, body mass 76.7 +/- 5.6 kg, VO2max 57.9 +/- 3.6 ml.kg(-1).min(-1); mean +/- s*) were filmed during an international game and their movement patterns were analysed. The majority of the total player game time was spent in the low-intensity motions of walking, jogging and standing (46.5 +/- 8.1, 40.5 +/- 7.0 and 7.4 +/- 0.9%, respectively). In comparison, the proportions of time spent in striding and sprinting were 4.1 +/- 1.1 and 1.5 +/- 0.6%, respectively. Their criteria for 'repeated-sprint' activity (*defined as a minimum of three sprints, with mean recovery duration between sprints of less than 21 s*) was met on 17 occasions during the game (*total for all players*), with a mean 4 +/- 1 sprints per bout. On average, 95% of the recovery during the repeated-sprint bouts was of an active nature. The results suggested that the motion activities of an elite field-hockey competition are similar to those of elite soccer, rugby and Australian Rules football. In addition, the investigation of repeated-sprint activity during competition has provided
additional information about the unique physiological demands of elite field-hockey performance.

Aziz, et al., (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. Body mass-normalised maximal oxygen uptake of 58.0+/-4.9 ml x kg(-1) x min(-1) of the group is comparable to values reported in the literature for team game players. No significant correlations were established between the fastest 40 m sprint time and maximal oxygen uptake (r=-0.21 and -0.08, p>0.05). Moderate correlations were established between maximal oxygen uptake and total time for the eight sprints (r=-0.346 and -0.323; p<0.05). 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.
Lemmink, Elferink-Gemser, and Visscher (2004) determined the reliability of two field hockey specific tests: the shuttle sprint and dribble test (ShuttleSDT) and the slalom sprint and dribble test (SlalomSDT). The shuttle sprint and dribble performances of 22 young male and 12 young female field hockey players were assessed on two occasions within 4 weeks. Twenty one young female field hockey players took part in the slalom sprint and dribble test twice in a 4 week period. The ShuttleSDT required the players to perform three 30 m shuttle sprints while carrying a hockey stick alternated with short periods of rest and, after a 5 minute rest, three 30 m shuttle sprints alternated with rest while dribbling a hockey ball. The SlalomSDT required the players to run a slalom course and, after a 5 minute rest, to dribble the same slalom with a hockey ball. There were no differences in mean time scores between the two test sessions. The mean differences were small when compared with the means of both test sessions. With the exception of the slalom sprint time, zero lay within the 95% confidence interval of the mean differences indicating that no bias existed between the two measurements. With the exception of delta shuttle time (0.79), all intraclass correlation coefficient values for the ShuttleSDT, met the criterion for reliability of 0.80. Intraclass correlation coefficient values for SlalomSDT were 0.91 for slalom sprint time, 0.78 for slalom dribble time, and 0.80 for delta slalom time. ShuttleSDT and the SlalomSDT are reliable measures of sprint and dribble performances of young field hockey players.

Unique requirements of field hockey include dribbling the ball and moving quickly in a semi-crouched posture. First, the net physiological strain due to
dribbling was examined. **Reilly and Seaton, (1990)** selected seven male hockey players completed a 5 min run on the treadmill at 8 km h\(^{-1}\) and 10 km h\(^{-1}\): subjects also ran at these speeds whilst dribbling a hockey ball. Dribbling increased energy expenditure by 15-16 kJ min\(^{-1}\) above that observed in normal running. Heart rates and perceived exertion were also increased. The posture in dribbling is likely to cause back ache among players: 53% of respondents (n = 81) reported experience of lower back pain. Finally, the shrinkage of spinal length during dribbling was examined. Subjects (n = 7) ran for 7 min on the treadmill whilst dribbling a ball. Shrinkage occurred at a rate of 0.4 mm min\(^{-1}\), which is greater than previously reported for other activities. The peculiar postural requirements of field hockey seem to cause physiological strain and spinal loading in excess of orthodox motion.

Sports are part of the sociocultural fabric of all countries. Although, different sports have their origins in different countries, many sports are now played worldwide. International sporting events bring athletes of many cultures together and provide the opportunity not only for athletic competition but also for sociocultural exchange and understanding among people. In the study of **Patel, Stier, and Luckstead, (2002)** reviewed five major sports with international appeal and participation: cricket, martial arts, field hockey, soccer, and tennis. For each sport, the major aspects of physiological and biomechanical demands, injuries, and prevention strategies are reviewed.
Competitive field hockey requires a substantial amount of muscular strength, speed, and cardiovascular endurance. It was unknown how these parameters of physical fitness change between preseason conditioning to postseason recovery. Therefore, Astorini, et al., (2004) selected division III female field hockey athletes (n = 13) completed tests of muscular strength, body composition, and maximal oxygen uptake (VO$_2$\textsubscript{max}) during each phase of their season. Muscular strength was assessed using 1 repetition maximum (RM) leg and bench press tests. Body composition was assessed by anthropometry (skinfolds [SKF]), circumferences ([CC]), and bioelectrical impedance analysis (BIA). Incremental treadmill testing was administered to assess VO$_2$\textsubscript{max}. VO$_2$\textsubscript{max} was unchanged during the season, although a trend (p > 0.05) was shown for a higher VO$_2$\textsubscript{max} during and after the season vs. before the season. Upper- (10%) and lower-body strength (14%) decreased (p > 0.05) during the season. Percent body fat (%BF) from BIA, fat mass (FM) from CC, and body mass index (BMI) were significantly lower (p < 0.05) in-season and postseason vs. preseason. In conclusion, preseason training was effective in decreasing %BF and increasing VO$_2$\textsubscript{max}, yet muscular strength was lost. Coaches should incorporate more rigorous in-season resistance training to prevent strength decrements. Moreover, these data support the superior levels of muscular strength and leanness in these athletes compared with age-matched peers.

*Speed and Agility*
Baker and Nance, (1999) analyzed the relation between measures of maximal strength and maximal power generated during exercises with similar movement patterns. Twenty professional rugby league players were examined for maximal strength in a 3 repetition maximum (RM) full squat and 3RM bench press exercise and for maximal power during a jump squat and incline bench press throw exercise. A 3RM power clean from the hang was also examined to determine if this exercise was related to lower or upper strength and power. The results indicated that maximal strength is highly related to maximal power in all the tests performed ($r = 0.55-0.89$, $p \leq 0.05$). The power clean from the hang is related more to lower-body squat strength and jump squat power ($r = 0.79$) than to upper-body bench press strength or incline bench throw power ($r = 0.51-0.55$). The practical application of the data suggested that while strength and power are highly related, a large degree of variance still exists. This may imply that further specific power training may be warranted to maximize power development, especially for the upper body.

Spencer, et al., (2005) studied field-based team sports, such as soccer, rugby and hockey is popular worldwide. There have been many studies that have investigated the physiology of these sports, especially soccer. However, some fitness components of these field-based team sports are poorly understood. In particular, repeated-sprint ability (RSA) is one area that has received relatively little research attention until recent times. Historically, it has been difficult to investigate the nature of RSA, because of the unpredictability of player
movements performed during field-based team sports. However, with improvements in technology, time-motion analysis has allowed researchers to document the detailed movement patterns of team-sport athletes. Studies that have published time-motion analysis during competition, in general, have reported the mean distance and duration of sprints during field-based team sports to be between 10-20 m and 2-3 seconds, respectively. Unfortunately, the vast majority of these studies have not reported the specific movement patterns of RSA, which is proposed as an important fitness component of team sports. Furthermore, there have been few studies that have investigated the physiological requirements of one-off, short-duration sprinting and repeated sprints (<10 seconds duration) that is specific to field-based team sports. This review examined the limited data concerning the metabolic changes occurring during this type of exercise, such as energy system contribution, adenosine triphosphate depletion and resynthesis, phosphocreatine degradation and resynthesis, glycolysis and glycogenolysis, and purine nucleotide loss.

**Sheppard and Young, (2006)** stated that at present, no agreement on a precise definition of agility within the sports science community exists. The term is applied to a broad range of sport contexts, but with such great inconsistency, it further complicated their understanding of what trainable components may enhance agility. A new definition of agility is proposed: "a rapid whole-body movement with change of velocity or direction in response to a stimulus". Agility has relationships with trainable physical qualities such as strength, power and
technique, as well as cognitive components such as visual-scanning techniques, visual-scanning speed and anticipation. Agility testing is generally confined to tests of physical components such as change of direction speed, or cognitive components such as anticipation and pattern recognition. New tests of agility that combine physical and cognitive measures are encouraged.

Gabbett, Jenkins, and Abernethy, (2009) stated that identified the purpose of this paper is to provide a brief review of the relevant literature on game-based training, and summarise the advantages and disadvantages of this approach to training. At present, studies investigating the effectiveness of game-based training are limited, with many of the suggested advantages and disadvantages of game-based training based on anecdotal evidence. Of the studies that have been performed, most have reported that game-based training offers a specific method of conditioning for team sport competition, but game-based training may not simulate the high-intensity, repeated-sprint demands of international competition. Game-based training has been reported to offer a safe, effective method of conditioning for team-sport athletes that results in comparable (and, in some cases, greater) improvements in physical fitness and performance than traditional conditioning activities. While technical instruction training has been associated with a higher volume of skill executions (i.e., more 'touches'), game-based training has been associated with greater cognitive effort - an important condition for skill learning. Indeed, studies investigating skill learning have reported comparable (and, in some cases, greater) improvements in skill
execution and decision-making following game-based training than training involving repetitious technical instruction. Collectively, these findings demonstrated the value of game-based training for improving skill and physical fitness in team sport athletes. Further studies investigating the long-term skill and physical benefits of game-based training are warranted.

**Strength and Flexibility**

Gabbett, King, and Jenkins, (2008) stated that Rugby league football is played in several countries worldwide. A rugby league team consists of 13 players (6 forwards and 7 backs), with matches played over two 40-minute halves separated by a 10-minute rest interval. Several studies have documented the physiological capacities of rugby league players and the physiological demands of competition, with the physiological capacities of players and the physiological demands of competition increasing as the playing level is increased. However, there is also evidence to suggest that the physiological capacities of players may deteriorate as the season progresses, with reductions in muscular power and maximal aerobic power and increases in skinfold thickness occurring towards the end of the rugby league season, when training loads are lowest and match loads and injury rates are at their highest. Player fatigue and playing intensity have been suggested to contribute to injuries in rugby league, with a recent study reporting a significant correlation (r=0.74) between match injury rates and playing intensity in semi-professional rugby league players. Studies have also reported a higher risk of injury in players with low 10-m and 40-m speed, while players with a low
maximal aerobic power had a greater risk of sustaining a contact injury. Furthermore, players who completed <18 weeks of training prior to sustaining their initial injury were at greater risk of sustaining a subsequent injury. These findings provide some explanation for the high incidence of fatigue-related injuries in rugby league players and highlight the importance of speed and endurance training to reduce the incidence of injury in rugby league players. To date, most, but not all, studies have investigated the movement patterns and physiological demands of rugby league competition, with little emphasis on how training activities simulate the competition environment. An understanding of the movement patterns and physiological demands of specific individual positions during training and competition would allow the development of strength and conditioning programmes to meet the specific requirements of these positions. In addition, further research is required to provide information on the repeated effort demands of rugby league. A test that assesses repeated effort performance and employs distances, tackles and intensities specific to rugby league, while also simulating work-to-rest ratios similar to rugby league competition, is warranted.

**Gorostiaga, et al., (1999)** investigated the effects of 6-weeks of heavy-resistance training on physical fitness and serum hormone status in adolescents (range 14-16 years old) 19 male handball players were divided into two different groups: a handball training group (NST, n = 10), and a handball and heavy-resistance strength training group (ST, n = 9). A third group of 4 handball goalkeepers of similar age served as a control group (C, n = 4). After the 6-week
training period, the ST group showed an improvement in maximal dynamic strength of the leg extensors (12.2%; P < 0.01) and the upper extremity muscles (23%; P < 0.01), while no changes were observed in the NST and C groups. Similar differences were observed in the maximal isometric unilateral leg extension forces. The height of the vertical jump increased in the NST group from 29.5 (SD 4) cm to 31.4 (SD 5) cm (P < 0.05) while no changes were observed in the ST and C groups. A significant increase was observed in the ST group in the velocity of the throwing test [from 71.7 (SD 7) km x h(-1) to 74.0 (SD 7) km x h(-1); P < 0.001] during the 6-week period while no changes were observed in the NST and C groups. During a submaximal endurance test running at 11 km x h(-1), a significant decrease in blood lactate concentration occurred in the NST group [from 3.3 (SD 0.9) mmol x l(-1) to 2.4 (SD 0.8) mmol x l(-1); P < 0.01] during the experiment, while no change was observed in the ST or C groups. Finally, a significant increase (P < 0.01) was noted in the testosterone:cortisol ratio in the C group, while the increase in the NST group approached statistical significance (P < 0.08) and no changes in this ratio occurred in the ST group. The present findings suggested that the addition of 6-weeks of heavy resistance training to the handball training resulted in gains in maximal strength and throwing velocity but it compromised gains in leg explosive force production and endurance running. The tendency for a compromised testosterone:cortisol ratio observed in the ST group could have been associated with a state of overreaching or overtraining.
Newton, Kraemer, and Häkkinen, (1999) studied whether ballistic resistance training would increase the vertical jump (VJ) performance of already highly trained jump athletes. Sixteen male volleyball players from a NCAA Division I team participated in the study. A Vertec was used to measure standing vertical jump and reach (SJR) and jump and reach from a three-step approach (AJR). Several types of vertical jump tests were also performed on a Plyometric Power System and a forceplate to measure force, velocity, and power production during vertical jumping. The subjects completed the tests and were then randomly divided into two groups, control and treatment. All subjects completed the usual preseason volleyball on-court training combined with a resistance training program. In addition, the treatment group completed 8 wk of squat jump training while the control group completed squat and leg press exercises at a 6RM load. Both groups were retested at the completion of the training period. The treatment group produced a significant increase in both SJR and AJR of 5.9+/-3.1% and 6.3+/-5.1% respectively. These increases were significantly greater than the pre-to postchanges produced by the control group, which were not significant for either jump. Analysis of the data from the various other jump tests suggested increased overall force output during jumping, and in particular increased rate of force development were the main contributors to the increased jump height. These results lend support to the effectiveness of ballistic resistance training for improving vertical jump performance in elite jump athletes.
Reverter-Masia, et al., (2008) in their study compared the conditioning services of Spanish sports teams: from soccer and basketball professional leagues, and top-division amateur leagues for handball, volleyball, indoor soccer, and field hockey. A survey was administered to those responsible for the conditioning preparation. The response rate was 82% (77 of 94). The teams were divided into class A and class B, with class A having the best performance. Fifty eight percent of the professional teams have hired a full-time person, with university degree, exclusively for the conditioning. The percentage was significantly less in amateur leagues for handball, volleyball, and field hockey: class A teams (41%), class B teams (0%). A small percentage of the Physical Conditioning Coaches (PCCs) continued their academic education (22%), and the consultation of scientific journals (5%). Only 6% of the PCCs did not mention deficiencies in the context of work. The main complaints are associated with the strength-training equipment and facilities. In class B teams of the amateur leagues, significant deficiencies were found in almost all the variables within the training environment. These results showed significant deficiencies in the conditioning services offered by teams to their players, especially in no-professional teams and in the teams with lower performance level. Spanish PCCs should take advantage of advances made through scientific research in the area of conditioning by acquiring Master's Degrees and consulting peer-reviewed journals. The club's managers and/or coaches must be aware of the importance of conditioning for improving the training environment. Both aspects would increase the likelihood that better training or rehabilitation procedures would be developed at the club.
Blazevich, and Jenkins, (2002) determined the effects of 7 weeks of high- and low-velocity resistance training on strength and sprint running performance in nine male elite junior sprint runners (age 19.0+/−1.4 years, best 100 m times 10.89+/−0.21 s; mean +/- s). The athletes continued their sprint training throughout the study, but their resistance training programme was replaced by one in which the movement velocities of hip extension and flexion, knee extension and flexion and squat exercises varied according to the loads lifted (i.e. 30-50% and 70-90% of 1-RM in the high- and low-velocity training groups, respectively). There were no between-group differences in hip flexion or extension torque produced at 1.05, 4.74 or 8.42 rad x s(-1), 20 m acceleration or 20 m ’flying’ running times, or 1-RM squat lift strength either before or after training. This was despite significant improvements in 20 m acceleration time (P < 0.01), squat strength (P < 0.05), isokinetic hip flexion torque at 4.74 rad x s(-1) and hip extension torque at 1.05 and 4.74 rad x s(-1) for the athletes as a whole over the training period. Although velocity-specific strength adaptations have been shown to occur rapidly in untrained and nonconcurrently training individuals, the results suggested a lack of velocity-specific performance changes in elite concurrently training sprint runners performing a combination of traditional and semi-specific resistance training exercises.

Coutts, Murphy and Dascombe, (2004) examined the influence of direct supervision on muscular strength, power, and running speed during 12 weeks of resistance training in young rugby league players. Two matched groups of young
(16.7 +/- 1.1 years [mean +/- SD]), talented rugby league players completed the same periodized resistance-training program in either a supervised (SUP) (N = 21) or an unsupervised (UNSUP) (N = 21) environment. Measures of 3 repetition maximum (3RM) bench press, 3RM squat, maximal chin-ups, vertical jump, 10- and 20-m sprints, and body mass were completed pretest (week 0), midtest (week 6), and posttest (week 12) training program. Results show that 12 weeks of periodized resistance training resulted in an increased body mass, 3RM bench press, 3RM squat, maximum number of chin-ups, vertical jump height, and 10- and 20-m sprint performance in both groups (p < 0.05). The SUP group completed significantly more training sessions, which were significantly correlated to strength increases for 3RM bench press and squat (p < 0.05). Furthermore, the SUP group significantly increased 3RM squat strength (at 6 and 12 weeks) and 3RM bench press strength (12 weeks) when compared to the UNSUP group (p < 0.05). Finally, the percent increase in the 3RM bench press, 3RM squat, and chin-upmax was also significantly greater in the SUP group than in the UNSUP group (p < 0.05). These findings showed that the direct supervision of resistance training in young athletes results in greater training adherence and increased strength gains than does unsupervised training.

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Tricoli, et al., (2005) stated that among sport conditioning coaches, there is considerable discussion regarding the efficiency of training methods that improve lower-body power. Heavy resistance training combined with vertical jump (VJ) training is a well-established training method; however, there is a lack of information about its combination with Olympic weightlifting (WL) exercises. Therefore, the purpose of the study was to compare the short-term effects of
heavy resistance training combined with either the VJ or WL program. Thirty-two young men were assigned to 3 groups: WL = 12, VJ = 12, and control = 8. These 32 men participated in an 8-week training study. The WL training program consisted of 3 x 6RM high pull, 4 x 4RM power clean, and 4 x 4RM clean and jerk. The VJ training program consisted of 6 x 4 double-leg hurdle hops, 4 x 4 alternated single-leg hurdle hops, 4 x 4 single-leg hurdle hops, and 4 x 4 40-cm drop jumps. Additionally, both groups performed 4 x 6RM half-squat exercises.

Training volume was increased after 4 weeks. Pretesting and posttesting consisted of squat jump (SJ) and countermovement jump (CMJ) tests, 10- and 30-m sprint speeds, an agility test, a half-squat 1RM, and a clean-and-jerk 1RM (only for WL). The WL program significantly increased the 10-m sprint speed (p < 0.05). Both groups, WL and VJ, increased CMJ (p < 0.05), but groups using the WL program increased more than those using the VJ program. On the other hand, the group using the VJ program increased its 1RM half-squat strength more than the WL group (47.8 and 43.7%, respectively). Only the WL group improved in the SJ (9.5%). There were no significant changes in the control group. In conclusion, Olympic WL exercises seemed to produce broader performance improvements than VJ exercises in physically active subjects.

Simenz, Dugan, and Ebben, (2005) in their study described the results of a survey of the practices of National Basketball Association strength and conditioning (NBA S&C) coaches. The response rate was 68.9% (20 of 29). This survey examines (a) background information, (b) physical testing, (c) flexibility development, (d) speed development, (e) plyometrics, (f) strength/power
development, (g) unique aspects, and (h) comments from coaches providing additional information. Results indicate, in part, that coaches assess an average of 7.3 parameters of fitness, with body composition testing being the most common. All coaches used a variety of flexibility development strategies. Results revealed that 17 of 20 (85.0%) of NBA S&C coaches follow a periodization model. Nineteen of 20 coaches (95.0%) indicated that their athletes used Olympic-style lifts. All coaches employed plyometric exercises with their athletes. The squat and its variations, as well as the Olympic-style lifts and their variations, were the most frequently used exercises. The survey serves as a review and a source of applied information and new ideas.

**Categorization of hockey players**

Nieuwenhuis, Spamer and van Rossum (2002) conducted a study to identify kinanthropometric, motor-physical and psychological variables and specific field hockey skills that influence field hockey performance at the age of 14 to 15 years. The two top girls” field hockey teams in the North West Province (South Africa) U/15 (under 15 age group) field hockey league (n = 27), as well as the two teams who ended at the bottom of the league (n = 25), were exposed to a test battery. The 52 subjects were classified according to their league results as successful and less successful. The test battery consisted of nine field hockey skills tests, 16 kinanthropometric tests and six physical-motor ability tests and two sport psychological tests. A statistical analysis of the data was done for descriptive purposes and statistical significances between the successful and less
successful players were determined. Results indicated meaningful differences in some variables. A prediction function was developed by them consisting of eight variables that successfully distinguished between successful and less successful 14- to 15-year-old female field hockey players.

To gain more insight into the mechanisms that underlie the development of interval endurance capacity in talented youth field hockey players in the 12–19 age band. A total of 377 measurements were taken over three years. A longitudinal model for interval endurance capacity was developed using the multilevel modelling program MLwiN. With the model, scores on the interval shuttle run test can be predicted for elite and sub-elite male and female field hockey players aged 12–19 years. A polynomial model of order 2 adequately represents development of the test scores over time. The fixed part of the model contains a different intercept and linear age term for boys and girls, and a common quadratic term; the random part of the model has a common level 2 variance and sex specific level 1 variances. The model was significantly improved by including differential effects of performance level for age and sex. A negative effect was found for percentage body fat, and positive effects for additional training and motivation. During adolescence, both male and female elite hockey players show a more promising development pattern of interval endurance capacity than sub-elite youth players. Percentage body fat, additional training hours, and motivation influence this development. However, differences between the individual players are still considerable (Elferink-Gemser, 2006).
Elferink-Gemser, et al., (2007) examined the performance characteristics that could help predict future elite field hockey players, they measured the anthropometric, physiological, technical, tactical, and psychological characteristics of 30 elite and 35 sub-elite youth players at the end of three consecutive seasons. The mean age of the players at the end of the first season was 14.2 years (s¼1.1). Repeated-measures analyses of covariance, with standard of performance and measurement occasion as factors and age as a covariate, showed that the elite players fared better than the sub-elite players on technical and tactical variables. Female elite youth players also scored better on interval endurance capacity, motivation, and confidence. Future elite players appear to have excellent tactical skills by the age of 14. They also have good specific technical skills and develop these together with interval endurance capacity better than sub-elite youth players in the subsequent 2 years.

Kruger (2010) investigated the sport psychological skills that discriminate significantly between successful and less successful female university field hockey players in order to emphasize the characteristics that need to be addressed in sport psychological skills training (SPST) sessions. The subjects consisted of 106 female university hockey players, categorized into a successful (players from the A division) and less successful group (players from the B division). The sport psychological skill (SPS) levels measured with the Psychological Skill Inventory (PSI) and the Ottawa Mental Skills Assessment Tool-3 (OMSAT-3) from the two groups were compared and reported. The results indicated that the successful group had better results in 66.7% of the variables that were measured in the study.
Practical significance was found in four of the 18 psychological variables that included achievement motivation, goal directedness, goal-setting and fear control. Furthermore, six variables discriminate significantly between the successful and less successful female hockey players, which included achievement motivation, stress reactions, fear control, self-confidence, mental rehearsal as well as imagery.

Keogh, Weber and Dalton (2003) in their study attempted to develop an effective testing battery for female field hockey by using anthropometric, physiological, and skill-related tests to distinguish between regional representative female field hockey (n = 39) and local club level (n = 35). Representative players were significantly leaner and recorded faster times for the 10-m and 40-m sprints as well as the Illinois Agility Run (with and without dribbling a hockey ball). Representative players also had greater aerobic and lower body muscular power and were more accurate in the shooting accuracy test, p<0.05. No significant differences between groups were evident for height, body mass, speed decrement in 40-m repeated sprints, handgrip strength, or pushing speed. These results indicated that %BF, sprinting speed, agility, dribbling control, aerobic and muscular power, and shooting accuracy can distinguish between female field hockey players of varying standards. Therefore, investigators suggested that talent identification programs for female field hockey should include assessments of these physical parameters.

Gabbett, et al., (2007) investigated the physical qualities of junior rugby league players competing at the elite and sub-elite level, and determine if pre-
season fitness measures were significantly different for the players selected to play in the first game of the season (i.e. starters) compared to the players not selected (i.e. non-starters). Thirty-six junior sub-elite and 28 junior elite rugby league players participated in this study. All sub-elite players were registered with the same junior recreational rugby league club, while elite players were members of a National Rugby League club junior development program. Subjects underwent measurements of anthropometry (height, body mass, and sum of seven skinfolds), speed (10m, 20m, and 40m 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. Elite players had better developed speed, change of direction speed, vertical jump, and maximal aerobic power than sub-elite players. Elite starters were taller and heavier than non-starters, while sub-elite starters were taller and had greater change of direction speed than non-starters. A high estimated maximal aerobic power was a common discriminator between starters and non-starters for both elite and sub-elite competitors. Those findings demonstrated that some physical qualities can discriminate starters and non-starters in elite and sub-elite junior rugby league teams.

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 (mean +/- SD age, 22.5 +/- 4.9 years) underwent measurements of standard anthropometry (height, body mass, and sum of 4
skinfolds), muscular power (vertical jump), speed (10-, 20-, and 40-m sprint), agility (L run), and estimated maximal aerobic power (multistage fitness test). In addition, 2 expert coaches independently assessed the playing ability of players using standardized skill criteria. First-grade players had significantly greater (p < 0.05) basic passing and ball-carrying ability and superior skills under fatigue, tackling and defensive skills, and evasion skills (i.e., ability to beat a player and 2 verse 1 skills) than second-grade and third-grade players. While no significant (p > 0.05) differences were detected among playing levels for body mass; skinfold thickness; height; 10-, 20-, or 40-m speed; agility; vertical jump height; or estimated maximal aerobic power, all the physiological and anthropometric characteristics were significantly (p < 0.05) associated with at least 1 measure of playing ability. The results of the study demonstrated 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. Those findings suggested 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. A game-specific training program that incorporates both physical conditioning and skills training may facilitate a greater transfer of physical fitness to competitive performances in rugby league.