ANTHROPOMETRIC CHARACTERISTICS AND PHYSIOLOGICAL PERFORMANCE VARIABLES OF MALE AND FEMALE JUNIOR HOCKEY PLAYERS IN KWAZULU NATAL

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Dedication

Dedicated to my children's love for hockey....

Rashaad

Tazkiyyah

and

Abduaqadir

Abstract

Anthropometric measures, physiological variables and skills tests were performed on subjects selected from the provincial KwaZulu Natal Junior Hockey teams in South Africa. The main purpose of this study was to establish a data base of norms for boy and girls in the U13, U14, U16, U18 and the U21 age groups. The tests were done at the beginning and at the end of season. The anthropometric measures included height, weight, percentage body fat and lean body mass; physiological variables included sit-ups, push-ups, sit-and-reach (flexibility), broad jump, winder and bleep tests, and the skills tests comprised a wide range of ball skill tests. As expected, anthropometric changes were observed across the age groups, due to growth. Amongst the older age groups the girls had reached height and weight values comparable to elite female players, but only the boys in the U21 had reached their adult height and were slightly taller than the elite male players. There was no significant difference in the profile between the attack and defence players in the boys, but amongst the girls the defence players tended to be heavier and taller than the attack players. In the physiological and skills tests there was no difference between positional players. In the comparison between pre and end season to determine the effectiveness of the training programmes, there was a change in the anthropometric characteristics because of growth. However, the physiological and skill tests revealed no consistent pattern of improvement in the test results from pre season to end season. This study provides the first set of norms for male and female junior hockey players in South Africa. Further studies are required to expand upon and update the data in the current study.

Declaration

This study represents original work by the author and has not been submitted for a degree to this or any other university or institution. Where use was made of the work of others, it has been acknowledged in the text.

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Contents

INTRODUCTION

The drive to excel in sport and to achieve national or international status is the desire of many youth the world over. The increased competitiveness in sport demands that players achieve their optimum performance levels in a methodical manner with clearly defined performance objectives and training programmes. This has motivated sports administrators, coaches, managers and players to spend time and resources evaluating their sports more scientifically. This requires that certain objective parameters be used to determine current performance and to monitor changes in performance. These parameters include anthropometric characteristics, physiological variables, and sports specific skills.

A large body of research in the area of elite players exists in almost all sports, for example, in athletics, basketball, field hockey and soccer (Withers, Roberts and Davies, 1977); kabaddi, basketball and volleyball, (Kansal, Verna, Sidhu and Sohal, 1983); field hockey (Bhanot and Sidhu, 1981; Sidhu, Gerwal and Verma, 1984; Reilly and Borre, 1992; Boyle, Mahoney and Wallace, 1994); American football (Bale, Colley, Mayhew, Piper and Ware, 1994); rugby (Carlson, Carter, Patterson, Petti, Orfanos and Noffal, 1994); soccer (Vecchiet, Calligras, Montanari and Resina, 1992; Chin, Lo, Li and So, 1992) and basketball (Smith and Thomas, 1991). The data available on the profile of elite players in the different sports provide a target which junior players can work towards in trying to achieve elite status. However, the profiles of elite players are not entirely relevant in the evaluation of sports performance in youth, who are still developing and growing. The musculo-skeletal system of the youth is still maturing and therefore their anthropometric and physiological characteristics will be different to those of elite players.

There is limited research detailing the physiological profiles of children and juniors in the various sports. Basic anthropometric, physiological and skills measures for juniors have been reported in a limited number of sports such as soccer (Berg, Lavoie and Latin, 1985; Viviani, Casagrande, Toniutto, 1993), wrestling (Sady, Thompson, Berg and Savage, 1983), athletics (Thorland, Johnson, Fagot, Tharp and Hammer, 1981,), volleyball (Thissen-Milder and Mayhew, 1991), gymnastics (Caldarone, Leglise, Giampietro and Berlutti, 1986), adolescent pole vaulters, (Sullivan, Knowlton, Hetzler and Woelke,1994), softball and netball (Withers and Roberts, 1981). However, very few studies report on the anthropometric and physiological characteristics of junior hockey players (Amort, 1981; Wilsmore and Curtis, 1992). Other studies on junior hockey players have concentrated on coaching, teaching and skills development (Stevens, 1980; Rate and Gamble, 1981; Spedding, 1987; Slocombe, 1988) and sport socialisation (Watson, 1986).

There are a number of international studies investigating the physiological characteristics of elite hockey players (Bhanot and Sidhu, 1981; Sidhu, *et al*, 1984; Reily and Seaton, 1990; Cibich, 1991; Reilly and Borrie, 1992; Shegrill, Singh and Tung, 1992; Boyle, *et al*, 1994). There is only one study that has described the anthropometric and physiological characteristics of elite male hockey players in South Africa (Scott, 1991). The findings in these studies confirm that field hockey requires a wide variety of physical attributes for successful performance.

There is no available research or normative data on junior hockey in South Africa. It is desirable that the profile of junior hockey players be researched and normative data recorded, so that strengths and weakness can be assessed and compared against a norm. Targets can be set for developing players and compared to the profile of elite hockey players and training programmes can be designed and monitored on an individual and or group basis to better meet the demands of the sport.

The primary aim of this study is to provide the first descriptive profile of junior hockey players in South Africa so that norms can be established. It is hoped that further large studies in schools will increase the pool of data so that more representative norms can ultimately be established. Once this norm is established the profiles of individual players can be taken and compared with the norms for early recognition of areas of weakness. This may ultimately lead to an improvement in the quality of junior hockey.

The role of comparison of an individual with descriptive norms in the talent identification of children with potential of success in a particular sport is debatable. It is not known whether one can identify potential elite sports men and women by performing physiological profile testing amongst the youth and comparing this profile with the elite profiles for the same sport. If a youth has a profile that resembles that of an elite player in a particular sport, does it necessarily follow that that youth has the potential of becoming an elite sportsman or woman? This issue is a subject of much research and will be discussed in more detail in the literature review below.

Angus, Sokolic and Sharret (1993), developed a field testing and computer software programme called FITTEST to assess the physical performance of hockey players in South Africa. However, one of the difficulties encountered in implementing this software was the lack of normative data on hockey players in South Africa. The objective of the FITTEST programme was to compute the profile of individual hockey players against a norm. This provides a profile of the player's fitness strengths and weaknesses against a norm. It would also provide a means of intra-individual comparison whereby fitness progress can be monitored. On the basis of this information the player can design his/her training programme to fit the particular requirements. The FITTEST also provides the average profile of the team. This profile assists the coach in assessing and designing the overall training programme for the team and when to modify the programme. The current study will provide the first set of normative data of youth so that the FITTEST programme can be implemented with *junior players*. With the collection of more data the normative data can be further updated in the future.

Anthropometric and physiological characteristics have been shown to vary with field positions in senior hockey, (Withers *et al*, 1977; Kansal, Verna, Sidhu and Sohal, 1983; Sidhu *et al*, 1984; Scott, 1991). A further aim of the current study is to determine if anthropometric and physiological characteristics differ according to field position in junior hockey.

The availability of descriptive data and standardised testing will facilitate the monitoring of training programmes. If the players are tested at the beginning and at the end of season a comparison can be made to determine the effectiveness of the training programme. Therefore, the third aim of the current study is to investigate the difference between the beginning and end of the season in these junior players.

The main objectives of this project are:

a) to collect normative data concerning anthropometric and physical performance profiles of junior hockey players in KZN.

b) to examine these variables in relation to the subjects' playing positions and to determine if there are any differences in the profile of the subjects with different playing positions.

c) to evaluate the effectiveness of current training programmes by comparing performance variables obtained at the beginning and end of season.

1. LITERATURE REVIEW

1.1 TALENT IDENTIFICATION

The issue of identifying sport-specific talent in youth by using screening tests has drawn much interest from proponents of this system as well as the critics.

Talent identification is defined as a screening device to predict which athletes are most likely to succeed in sport (Woodman, 1985). Until recently this has been based on variable factors, such as, exposure to a sport, the opportunity to play a particular sport, the influence of role models in parents or family, parental support and natural ability. Very often this is based on the coach's intuition and the athlete's performance compared to others of the same chronological age (Bar-Or, 1975; Woodman, 1985). This method is unscientific and is of a subjective nature because it does not take into account factors such as different rates of maturation (Bompa, 1985; Woodman, 1985).

Talent identification has lately become popular in many parts of the world. In Eastern Europe and in particular the former East Germany and USSR, it has been an established system for a number of years and sophisticated scientific methods have been employed. Schools have been established which specialise in development of sports-oriented youth. In these countries, talent identification and the selection of potential elite players has been refined by technology. Training analyses are done to assess young competitors' progress through a continual monitoring process (Riordan, 1987). In other countries this is also becoming popular, with specialist sports schools in Britain, Australia and India (Grisogono, 1991).

Bloomfield (1980) quotes Dr Alois Mader, former sports medicine chief of the East German Sports and Physical Education Institutes, "In the East we determine scientifically at a very early age, apparently with good accuracy, whether or not a child has any chance of becoming an Olympic athlete. The chosen receive the chance to develop their obvious potentials through a rigorous training programme" (Woodman, 1985).

Jarver (1981), reports that the search for talent in the former USSR is based on a carefully planned system of selection over a period of several years. Information is gathered on a number of performance factors at various ages, including the rate of improvement and biological age. In 1985, Woodman had suggested a national talent identification system for Australia which was based on a talent identification study undertaken in Australia. Certain countries consider talent identification as a valuable tool in identifying potential sports achievers who may be directed to the sports in which they are likely to succeed and to point out to others their inherent limitations in certain sports (Woodman, 1985).

This is a relatively new scientific endeavour and the purpose of research in talent identification, is to provide a more objective approach to the prediction of future success (Bar-Or, 1975) and to the selection of potentially gifted athletes (Bompa, 1985).

The initial step in talent identification research is task analysis of the sport to identify those fundamental attributes and capacities which are important for athletic success (Kerr, Booth, Dainty, Gaboriault and McGavern, 1980; Kovar, 1981; Jarver, 1981, 1982; Griffiths, 1984). Some variables that have been considered include: (1) anthropometric measurements (Carter, 1970; Bar-Or, 1975; Kerr *et al*, 1980; Bompa, 1985), (2) biological age and maturation status (Kantiz and Bar-Or, 1974), (3) aerobic capacity, anaerobic capacity and power (Bar-Or, 1975; Kerr, Dainty, Booth Gaboriault and McGavern, 1980), (4) genetics and heredity (Bar-Or, 1975; Kovar, 1981; Bompa, 1985), and (5) bio-mechanical factors (Jensen, 1979).

Each sport has its own specific profile and examples of sport specific talent identification profiles are provided by Alabin, Nischt, and Jelimov (1980) in track and field, Blanksby (1980) in swimming, Dick (1979) in track and field, Shakespear (1980) in rowing, Tabatchink (1979) in sprinting, Travin, Shatshin and Upir (1982) in distance running and Telford (1980) in cycling, kayaking and rowing.

1.2 FACTORS AFFECTING HOCKEY PERFORMANCE

There are a variety of factors which influence the successful hockey performance of an individual. The key factors can be determined by an analysis of the tasks involved in hockey. The analysis must show exactly what occurs in the performance of the game and the demands made upon the player (Woodman, 1985).

A game of hockey involves aerobic power, as the game lasts for 70 minutes, short bursts of running (speed) followed by rapid recovery periods of lower intensity, anaerobic power (short sprints), striking with a hockey stick (power), agility and flexibility to move from one position to another. Skill is also required to dribble the ball with a hockey stick and to be able to slap, hit and flick the ball with accuracy.

This requires upper arm strength and hand-eye-co-ordination (Wilsmore and Curtis, 1992).

The morphological and physiological characteristics of elite *male hockey players* have been recorded by Withers *et al* (1977); Withers, Roberts and Davies (1977); Verma and Kansal (1980); Kansal *et al* (1980); Maunsell (1980); Armstrong (1981); Alexander (1983); Bhanot and Sidhu (1983); Kansal *et al* (1983); Sidhu *et al* (1984); Mathur (1984); Toriola, Salokun and Mathur (1985); Proulx and Sexsmith (1987); Singh, Singh, Chawla and Singh (1987); Ghosh, Khanna, Ahuja, Mazumda and Mathur (1988); Scott, Manley and Williams (1988); Marshall (1989); Reilly and Seaton (1990); Scott (1991); Shukla, Sharma and Sheikh, (1991); Reilly and Borrie (1992); Boyle *et al* (1994) in *female hockey players* by Bobb (1978); Chapman (1979); Withers and Roberts (1981); Sidhu *et al* (1984); Sidhu and Grewal (1984); Reilly and Bretherton (1986); Proulx (1987); Wilsmore (1987); Mokha, Sidhu, Kaur and Singh (1990); Mokha, Kaur and Sidhu (1992). The factors detailed in the above studies include amongst others, height, weight, percentage body fat, lean body mass, body fat, aerobic and, anaerobic capacity, power, speed, strength and hockey specific skills. These factors and the relevant findings in the above studies are discussed below.

Height

Height is an important factor in many sports. In volleyball and basketball height is an advantage whereas in hockey it may be somewhat of an disadvantage to be tall because of the stooping posture (Scott, 1991). In male hockey players, the mean height in the Indian winning team at the Tokyo Olympics was 1.73m (Hirata, 1966). The Pakistani and non-Asian teams were taller. The small size of Indian international players reported in other studies reflects the smaller stature of the Asian population rather than elite hockey players (Bhanot & Sidhu, 1981). The elite South African players had a mean height of 1.76m (Scott, 1991). The mean height of female hockey players tends to range from 1.62 to 1.65m. This is taller than cross country skiers, alpine skiers and gymnasts, but shorter than the mean values for netball and softball (Reilly and Secher, 1980).

Arm length

Scott (1991) felt that because hockey involves playing with a hockey stick to control and pass the ball, arm length would be a factor affecting performance.

However, in her study there appeared to be no relationship between arm length and playing ability and therefore arm length was not included in the current study.

Body weight

Body mass is also an important factor in hockey, as there are positional differences in body mass between forwards, backs and goalkeepers (Sidhu *et al*, 1984). Amongst top level Indian women hockey players, Kansal *et al* (1980) found that goalkeepers and backs were heaviest followed by halves and forwards respectively. Malhorta, Joseph and Gupta, (1974) found that the goalkeepers were shortest, had the lowest percent lean bodyweight and the highest percent body fat; the forwards were the lightest, with the least percent body fat and the highest lean body weight, the backs were the tallest with percentage body fats and lean body mass intermediate between goalkeepers and forwards. Similar difference were found in the studies by Bhanot and Sidhu (1983), in top class Indian hockey players; by Bale (1981), Bale and McNaught-Davis (1983) amongst top class English female hockey players and by Carter, Rendle and Gayton (1981) amongst the hockey players at the 1976 Olympic games in Montreal from Argentina, Kenya, Malaysia, Australia and New Zealand where most of these players had somatotypes in the dominant mesomorphy region of the somatochart but there was a wide dispersion of physiques. Carter *et al* (1981) suggest, these variations in somatotypes probably reflect both the ethnic grouping and playing position.

The mean body weight values for males in the Indian Tokyo Olympic team was 69kg Hirata (1966). The Pakistani and non-Asian teams were heavier. The small size of Indian international players reported in other studies reflects the smaller stature of the Asian population rather than elite hockey players (Bhanot & Sidhu, 1981). The elite South African players had a mean weight of 75kg (Scott, 1991). The mean body weight values for female players range from 58 to 63kg (Reilly and Borrie, 1992) however, in the Asian teams (notably Indian and Malaysian) studied by Verma *et al* (1979) the mean weight was 51 kg. Goalkeepers were the heaviest with forwards and halves being the lightest

Percentage body fat

Scott (1991), in her study on elite male hockey players, found that they had a fairly low percentage body fat of 11.1%, whereas, Withers *et al* (1977) found that South Australian state male hockey players had a percentage body fat of 16.7%. Elite female hockey players had a percentage body fat ranging from 15.7-18.9% in the Canadian

Olympic hockey team (Ready and van der Merwe, 1986). Withers and Roberts (1981) reported a value of 25.3%, Reilly *et al* (1985), reported a figure of 25.8% for Welsh national players whilst values of 23 and 22.9% were found in English elite squad and country players, respectively (Reilly and Bretherton, 1986). Withers *et al* (1987), found a mean of 20.2% for South Australian players. Reilly and Secher (1990) reported a spread of mean values in the literature for female hockey players ranging from 16 to 26%. The lower values were found in the elite players close to peak fitness for international tournaments. In summary it would appear that a lower level of body fat is not essential for elite performance. However, it must be noted that the accurate measurement of skinfolds, using a skinfold calliper is dependent on the operators that are taking the measurements and therefore, an inter-operator variability of measurements will be expected. Therefore, any comparison between studies need to viewed with caution.

Aerobic capacity

The major non-skill physiological characteristics related to performance are endurance (aerobic capacity), anaerobic capacity, strength, speed, power, and flexibility (Reilly and Borrie, 1992). The relative combination of these characteristics is dependent upon field position (Bale, 1986; Reilly and Borrie,1992). As the interest in hockey increases amongst the youth and as the game becomes more competitive, a higher degree of physical fitness is required.

A pre-requisite for these tests is the need to analyse a game of hockey to determine the key elements of physical fitness. A study by Shergill *et al* (1992) evaluated the importance of a set of specific physical fitness components as contributors in hockey playing ability. Of the 22 tests selected to measure fitness components it was found that an endurance run test, the standing broad jump test, grip strength (left hand), the vertical jump test, the wrist flexion test, age, height, weight were significantly important in evaluating hockey performance. Also, the results failed to find support for speed as an important predictor of hockey playing ability.

Since the introduction of the artificial turf in 1976 and its widespread use and the natural evolution of the game, the demands of the game have changed significantly. Therefore, the results of earlier studies must be viewed with caution. One must also consider that the construction of synthetic surfaces was more prolific in Western Europe and Australia than in India and Pakistan during the 1980's. It is possible that this may lead to the differences between the playing populations of different countries within this period. Therefore, caution must be taken in comparing European, Australasian and Asian studies (Reilly and Borrie, 1992).

A game of hockey demands that players have an adequate aerobic power capacity to be able to play continuously for the duration of the game. Reilly and Borrie, (1992) analysed the physiological cost of energy expenditure of playing hockey and placed it in the category of 'heavy exercise' with reported oxygen consumption (VO_2) values during a game of 2.26 L/min. Boyle *et al* (1994) studied the competitive demands of elite male field hockey using heart rate and VO_2max. They found that the mean O_2 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 range of maximal aerobic power reported in the literature for male hockey players reviewed by Reilly and Secher (1990), is 48 to 65 ml/kg/min. Withers *et al* (1977) found a mean VO_2max of 64.1 ml/kg/min amongst South Australian state hockey players. It would appear that an aerobic power in excess of 60 ml/kg/min is required for elite level play. Ghosh *et al*, 1988, found that the mean VO_2max of 3.74 L/min (61.1 ml/kg/min) in elite Indian hockey players comparable to world class players, however, there was no significant difference between the maximal aerobic capacity of different field positions.

In female players, the maximal aerobic power has been shown to range between 45 to 59 ml/kg/min (Reilly and Secher, 1990). The elite English squad had mean values of 46 ml/kg/min whereas the country players had 41 ml/kg/min (Reilly and Bretherton, 1986). American (Zeldis, Morganroth and Ruber, 1978) and Australian (Withers and Roberts, 1981) international players both had reported mean values of 50 ml/kg/min.

Reilly and Seaton (1990) measured energy expenditure in hockey players while dribbling a ball on a treadmill at speeds of 8 and 10 km/h. They found that dribbling increased the energy expenditure by 15 to 16 kJ/min above that observed in normal running. The greater additional energy cost in field hockey compared to dribbling a ball in soccer (Reilly and Ball, 1984) may be accounted for partly by postural factors and also the arm and shoulder exercise in using the hockey stick. Additionally, the intermittent nature of activity during match-play, the physiological costs of accelerating, decelerating and changing the direction of motion, add to the energy requirements (Reilly and Borrie, 1992).

These studies reflect that hockey places a heavy demand on the aerobic system and requires players to expend energy at relatively high levels. Fatigue, exhaustion or lack of stamina are limiting factors in a game of hockey and it could be classified as an endurance sport similar to soccer (Berg *et al*, 1985). This requires the aerobic power systems in the body to be conditioned to deliver the energy requirements.

Fox (1984), included hockey with lacrosse and soccer among sports with a 30% aerobic, 70% anaerobic contribution to energy expenditure while Sharkey (1986) classified the game as bordering on the aerobic side (40% anaerobic and 60% aerobic) of the energy continuum, grouping it with sports of mixed demands including canoeing, kayaking, lacrosse, motorcross and mountaineering. Reilly and Borrie (1992) suggest that the game should be viewed as aerobically demanding with frequent though brief anaerobic efforts superimposed.

Whatever the ratio of these two systems, which will vary with individual players and the standard of play, it is evident that the conditioning programme for field hockey players should include both aerobic and anaerobic training. Withers *et al* (1977) proposed that the demands of sports such as field hockey require a player to possess a high degree of anaerobic power together with a maximal oxygen uptake value approaching that of a long distance runner.

Anaerobic power

A number of studies have been undertaken to determine the anaerobic capacities of hockey players. Reilly and Borrie (1992) studied male and female hockey players. They report that the anaerobic power output of the female compared favourably with other groups of sportswomen. They have also shown a difference in the anaerobic capacity between elite and county level female players. In the male players the anaerobic power output has been shown to be the same as that of soccer players and better than other sports, such as basketball and also higher than reference norms. Ghosh, Goswami, Mazumdar and Mathur (1991) have shown that the blood lactate levels after a game of hockey were higher in the senior players than in the junior players, which reflects that the seniors played the game with more intensity. Bhanot and Sidhu (1981,1983) studied anaerobic power in relation to field position and found that the goalkeepers had greater anaerobic power than the forwards in vertical velocity (i.e. a stair run test). Bhanot and Sidhu (1981) studied anaerobic power among players in hockey, football, (field games) and volleyball and basketball (court games), they found that football players had the highest vertical velocity followed by hockey, volleyball and basketball. They concluded that field game players have higher vertical velocity than court game players and volleyball players have higher maximum anaerobic power than football, hockey, and basketball players. Ghosh *et al* (1988) reported that the mean O_2 debt of 5.7 L (94.4 ml/kg/min) in elite Indian hockey players was comparable to world class players. Forwards and halves had significantly higher anaerobic work capacity than the full backs. From these studies it can be concluded that hockey players need a well developed anaerobic system for energy supply and therefore this needs to be included in a fitness assessment.

Speed and acceleration

A game of hockey demands that the player has the capability to accelerate and decelerate quickly. Acceleration is more critical to hockey performance than maximal speed (Reilly and Borrie, 1992). According to some studies in soccer, only approximately 5% of the sprints in a game reach a distance of 60m, whilst most are less than 20m (Vecchiet L, Calligras B, Montanari L and Resina C, 1992). Such a study has not been undertaken for field hockey. However, due to the close similarity between soccer and hockey such a value may be comparable to hockey.

A game of hockey requires a high level of strength and power to accelerate the body mass. In an analysis of state level Australian sportsmen, Withers *et al* (1977) found that hockey players had a relative leg power value, as measured on a stair test of 15.2 W/kg when compared to football players with a value of 16.1 W/kg, basketball players with a value of 14.1 W/kg and runner/walkers with a value of 14.0 W/kg. Scott (1991) used the standing broad jump in measuring elite male hockey players in South Africa. The mean value of 2.3m was considered 'very good' according to the Power Rating Scale of Corbin, Dowell, Lindsley and Tolson (1981). A high peak power output from the leg is, therefore an important part of the physiological profile of the elite player (Reilly and Borrie, 1992). Unfortunately, no specific data are available on the effectiveness of sprint training regimens in improving sprint time and match performance in field hockey. However, male hockey players have been shown to have similar leg power profiles to male soccer players (Withers *et al*, 1977).

Speed endurance and agility

Hockey is a "strength-endurance" sport which involves several skill patterns that are "open" (i.e. performance influenced by tactics, response to opponent's actions, etc.) which complicates the measurement of strength and power as opposed to sports that involve a single "closed" skill pattern (e.g. rowing). The process can be simplified by correlating tests of strength and power with single, measurable skills rather than overall performance (MacDougal, Wenger and Green, 1991).

Grip strength

Hockey is a game which requires the manipulation and movement of the ball using a stick 76-84 cm in length and 0.56-0.77 kg in weight. This requires good strength to grip and control the stick during a game (Scott, 1991). Advances in stick construction, over the past decade, have allowed players to reach greater levels of ball control and have also increased hitting power. The crook of the stick has become lighter and smaller in the more recent years, giving rise to improvements in ball control. The physical properties of the stick have also changed, from sticks constructed purely from wood to sticks that are amalgams of wood and light-weight man-made materials such as Kevlar and aluminium. These changes have increased the rigidity of sticks, thereby allowing greater pace to be imparted to the ball since less energy is lost at impact in the vibration of the stick. It is now possible to attain a greater velocity on shot and pass with the same level of muscular work. Scott (1991) reported greater grip strength values in South African hockey players (54 kg for the right hand and 53.1kg for the left hand) than in male college students. Despite the fact that almost all players were right hand dominant, the difference between left and right grip strength was insignificant. This was thought to reflect the fact that players have to use both hands, or either hand unilaterally, in controlling the hockey stick during a game (Reilly and Borrie, 1992). Hockey demands dribbling the ball with a hockey stick in a crouched position. The muscle groups of the arms and the upper body have to be strong to manipulate the stick and ball.

Muscular Endurance

The use of a hockey stick demands repetitive movement of the smaller muscle groups of the upper body that may result in local fatigue. Therefore, upper body strength is required to hit, slap hit, push and flick the ball. Arm and shoulder girdle strength is considered particularly important in defensive tackling as well as for strength on the ball when in possession. It is also considered crucial in minimising errors in basic skills, as fatigue induces gross body movements rather than fine manipulative ones (Wilsmore and Curtis, 1992).

Abdominal strength is crucial to explosive running and powerful hitting as it provides the muscular link between the upper and lower body and thereby assists force summation (Wilsmore and Curtis, 1992).

Thus, muscular endurance is essential for hockey and would be a limiting physiological factor in hockey performance and therefore must be tested in any fitness assessment programme.

Flexibility

A game of hockey involves a great deal of stopping and starting, changing direction, lunging and dodging, it is therefore essential that hockey players have a good a range of movement (a measure of flexibility) in order to prevent or at least reduce the number of injuries (Scott, 1991).

The agility required in hockey necessitates flexible joints to be able to perform the required skills, in particular the lower spine, hips, wrists and shoulders. The skills and movement patterns associated with hockey involve movement at a number of joints. While extreme range of movements may not be required in hockey except perhaps for the goalkeeper an overall level of flexibility is required as in most sports.

Skills

The skills needed to play hockey require general physiological attributes such as, good sight and hearing ability, the ability to respond to other players, hand-eye-co-ordination, and neuromuscular co-ordination. Whilst some of these are genetically endowed, players still have the ability to enhance their skills.

Very few studies (Wessel and Koenig, 1971; Reilly and Bretherton, 1986) have been undertaken to test hockey skills. According to Reilly and Borrie (1992), there has been little attention given to the design of field tests for the game. Some tests incorporated a dribble, dodge, circular tackle and drive (Wessel and Koenig, 1971). Other non-standardised tests were built around 2 or more of the fundamental game skills, but failed to produce the physiological stress under which skills are executed in match-play (Reilly and Borrie, 1992).

Reilly and Bretherton (1986) used 2 field tests in their evaluation of English elite female players. The first was a 'T' course in which the players had to dribble the ball around skittles. As many circuits as possible had to be performed in 2 minutes. According to Astrand and Rodahl (1986) sports which engage large muscle groups for 1 minute or more tax VO_2max and so this test implies a high aerobic loading.

Performance on the test was found to correlate significantly with both aerobic and anaerobic power and differentiated between elite and county level players (Reilly and Borrie, 1992).

The second field test was a distance and accuracy test (Reilly and Bretherton, 1986). This involved a combination of dribbling and hitting the ball at a target, a set sequence being repeated as often as possible within 2 minutes. The distance travelled by the ball was measured and the relative accuracy was calculated by the number of accurate shots as a percentage of the number of hits. The accuracy in this test was significantly related to somatotype of the subjects.

1.3 CHARACTERISTICS OF YOUTH SPORTSMEN & WOMEN

For decades youth have participated in various sports programmes but the effects of these programmes on various physical and physiological characteristics have not been completely examined (Berg *et al*, 1985). Biological age and maturation (Bompa, 1985; Woodsman, 1985) significantly affect performance of youth in sports. It is therefore necessary to understand the growth and development of youth and its impact on sports performance. For any study collating normative data on youth, who are going through a growth phase, a background knowledge of this process and how it affects their physical characteristics is essential.

Growth spurts

Boys and girls have a similar skeletal growth pattern until the adolescent growth spurt which takes place between the ages of 10-12 years in girls and 12-14 years in boys, lasting about two years in each case (Grisogono, 1991). Due to this difference, there are some girls who will be bigger, heavier and stronger than boys of the same age, up to the age of about 12 and therefore in mixed competitions in a younger age group girls may perform better than boys of the same age (Grisogono, 1991).

The growth spurt occurs at a different chronological age in different individuals and thereafter chronological age may not reflect biological age. This reflects the difference between chronological and biological age. This difference has important implications for age-group sport. According to Woodman (1985) this difference could be up to six years. For example, a girl of twelve could have a biological age anywhere between nine and fifteen and a boy of fourteen between eleven and seventeen. Children who mature earlier are bigger and stronger, often dominate age group sports and are considered future champions. Later, when more serious competition begins, the earlier maturers may lose their initial advantage, especially if their inherited potential is limited, whereas, the late maturer who trains intensely despite early limitations may advance at a later stage to much higher levels of performance. The initial difference may demoralise and frustrate the late maturers who in their early involvement in sport cannot keep up with the early maturers. The opposite also applies when the late maturers out perform the earlier maturers. This frustration leads to drop out from sports (Grisogono, 1991; Woodman, 1985) and therefore physiological testing of children will help determine their profile and classify them according to their biological group instead of the traditional age group. Woodman (1985) states that "any identification based solely on performance and chronological age will result in many serious mistakes with many potential champions eliminated." A fairly accurate way of determining the biological age of a child is an X-ray of the vertebral column or the wrist, to show the degree of bone development (ossification) (Koete and Schmidt, 1984). Another method to determine maturation is to assess the stages of development of the genitalia, the growth of pubic hair in both the boys and the girls and, in addition, the development of the breasts in the girls (MacDougall *et al*, 1991). Other methods include using longitudinal stature data tables and tridemensional computer graphics growth curve analysis (MacDougall *et al*, 1991).

Puberty

In boys, the onset of puberty coincides with the growth spurt and does not appear to be affected by physical activity. However, in girls it usually starts after the growth spurt is complete. Strenuous physical activity in girls in the pre-pubescent phase may delay the onset of puberty. It has been found that in competitive swimmers the onset of menarche was delayed by six months for every year of serious training before menarche: swimmers who started intensive training after menarche had begun to menstruate at 12 years and 6 months, whereas those who had started training before menarche began menstruating at an average of 15 years old (Grisogono, 1991). Among runners, girls who were training before menarche were on average, 15 years and 2 months when they had their first menstruation, compared to 12 years and 9 months in those who started training after menarche (Frisch, 1984; Grisogono, 1991). Physiologically such a delay in menarche should not in itself be harmful, so girls can usually expect a normal adulthood with a normal chance of conceiving (Grisogono, 1991).

Bodyweight

The increase in bodyweight occurs in boys and girls at different times. Between the ages of 7-10 years the increase in bodyweight due to growth is similar, with the girls slightly lighter than boys. However, at about the age of 11 years the girls increase by approximately 2 kg more than the boys, whose weight increases between the ages of 12 and 13 years. By 14 years the boys' weight is similar to the girls (Grisogono, 1991). During earlier childhood, girls have only slightly more body fat than boys (Palgi, Gutin, Young and Alexandro, 1984). Grisogono (1991) reported mean values at the age of 8 years of 18% and 16% body fat for boys and girls respectively. During and following the growth spurt, girls tend to accumulate relatively more fat, increasing to a mean body fat of 25% at 17 years, while boys tend to decline to 12-14% body fat at the same age (Grisogono, 1991). There is however, a large inter-individual variation in these values.

Strength

For the normal development of the musculo-skeletal system in youth, regular physical activity is essential. A significant reduction of physical working capacity, including muscle strength, may occur in children who do not exercise regularly (Maceck, 1985).

As children grow their bodies change in shape and composition and in general become linear, less bony, and more muscular with age. In longitudinal studies of strength expectancy in boys aged 6 to 18 years, it was reported that as the boys increase in size, their growth in strength performance is greater than geometrical expectancy. Until the postpubescent period, girls presumably have a similar dimensional increase. Although, as discussed by Ross and Ward (1984), the proportional increase in upper arm girth of girls is far exceeded by boys, suggesting an increasing sexual dimorphism in upper body strength (MacDougall *et al*, 1991).

Children 9 years and older were tested in the laboratory to measure their calf strength, where it was found that the contraction speed and fatigue resistance remained constant with increasing age, with no difference between the sexes. Strength remained the same between 9-11 year olds and thereafter increased with age (Grisogono, 1991).

Strength naturally increases with growth (age), probably reaching a peak during the adolescent growth spurt in girls, and a year after in boys (Potthast and Klimt, 1988).

Nielsen, Nielsen, Brendt-Hansen and Asmussen (1980) suggested that suitable resistance training in girls results in strength gains throughout their phases of development, before, during or after puberty. Similarly, boys can also train to improve their strength. There is uncertainty whether strength trainability remains the same throughout the growth phases and whether the pre-pubescent might have greater trainability in strength than older age groups (Nielsen *et al*, 1980) or vice versa (Vrijens,1988). In a study on 200 children from 7 to 12 years, consisting of swimmers, tennis players and non-competitors, no difference in strength was reported, except that the swimmers had better leg extension. However, none of the groups had done any strength training and this was attributed to the strength gained in the actual sport (Bloomfield, Blanksby, Ackland and Elliott, 1985).

The anabolic effect of testosterone in boys during puberty results in large increases in muscle bulk and strength. Girls do not show this marked increase but show a more gradual rise in strength from a younger age than boys (Grisogono, 1991).

Flexibility

Flexibility refers to the range of motion at a single joint or a series of joints and reflects the ability of the muscle-tendon units to stretch within the physical constraints of that joint. It is well known that flexibility in general decreases with growth (Grisogono, 1991).

This is most noticeable during the growth spurts, when the increase in skeletal length causes the attached muscles to stretch over the bones, the muscles become thin and long for a period, until they gain bulk and strength (O'Neil & Micheli, 1988). If the adolescent is involved in a sport that causes certain muscles to shorten they become tight, limiting joint range. For example, many young elite squash players, because of the crouching position of the game, gradually lose the ability to straighten their knees fully. After a growth spurt, an imbalance between muscle strength and flexibility, is a contributing factor to muscle and or joint injury (Ekstand & Gillquist, 1983; Wiktorsson-Moller, Oberg, Ekstrand and Gillquist, 1983; Wallace, Mangine and Malone, 1985; Safran, Garett, Seaber, Glisson and Ribbeck, 1988)

VO_2max

Between the ages of 5 and 10 years, aerobic power is similar in both sexes. Due to their earlier growth spurts, girls may surge ahead. However, from about 14 years onwards their aerobic power tends not to improve, mainly because of their increase in percentage body fat at this stage of development. Boys on the other hand, continue to improve their aerobic power until the age of 18 (Grisogono, 1991).

The mean VO_2max reported for 13 year old boys and girls is 47.8 ml/kg/min and 39.5 ml/kg/min respectively (Armstrong, 1981). For 16-19 year olds the value is 51.7 ml/kg/min for boys and 40.0 ml/kg/min for girls (Anderson, Henckel and Saltin, 1987). Some investigators have detected no significant differences in VO_2max of trained and untrained children (Daniels and Oldridge, 1971; Sobolova, Seliger, Grussova and Machoocova and Zeleneka, 1971). Cunningham, Telford and Swart, 1976, reported a VO_2max of 56.6 ml/kg/min in 15 hockey players whose mean age was 10.6 years. The players, members of a select team who participated in organised hockey for 4.4 years had a considerably higher VO_2max than those reported by other investigators, which suggest that aerobic capacity of successful youth athletes appears to be equivalent to that of trained adult players in the same sport (Ferguson, Marcotte and Montpett, 1971; Cunningham and Eynon, 1973). The above finding may express, however, the effect of genetic endowment (Astrand, 1960; Andrew, Becklake, Guleria and Bates, 1972) and may be an exceptional case. In non-elite soccer players age 14 to 18 years, Caru, Coultree, Aghemo and Limas (1970) reported mean values for VO_2max ranging from 42.3 to 50.2 ml/kg/min. These values were not significantly different in comparison to those of sedentary control group. These findings of Caru *et al* (1970) of no difference between mean values of VO_2max of soccer players and controls were confirmed in study by Berg *et al* (1985) amongst youth soccer, where the mean age was 11.8 years and 11.5 years respectively.

The trainability of children as regards maximal oxygen uptake is controversial. While a number of studies have indicated little or no training effect (Daniels and Oldridge, 1976; Stewart and Gutin, 1976) others have reported significant changes in VO_2max (Kobayshi, Kitamura, Miura, Sodeyama, Murase, Miyashita and Matsui, 1978). Shepherd (1971) postulated that most children are active enough to have achieved near maximum values for O_2 uptake without structured training. Consequently he believed that scores of 48-50 ml/kg/min represent maximum values for group data. Grisogono (1991) states that training programmes certainly increase the aerobic power in both sexes but no specific year can be identified in which the greatest benefit occurs. There is a large amount of inter-individual variation in the response to the same training programmes.

Anaerobic power

Younger children have a lower capacity to work anaerobically compared to adolescents, who themselves are inferior in this to adults (Grisogono, 1991). After allowing for differences in bodyweight, the anaerobic energy produced by an 8 year-old is only 70% of that of an 11 year-old, which in turn is less than half of a 14 year-old (Kurouski, 1983). It has been shown by Bar-Or (1983) that a young child's muscle has a lower rate of glycogen utilisation and much less glycogen and creatine phosphate stores. It has also been shown that children have lower maximal concentrations of lactate in blood and muscle at various high percentages of maximum effort compared to adults at similar intensities (Eriksson, Karlsson and Saltin, 1971; Simon, Berg, Dickhuth, Simon-Alt and Keuk, 1981; Inbar, Bar-Or, 1986). Inbar and Bar-Or, 1986 have shown that children have lower mechanical power output than adolescents and young adults when assessed by the Margaria step running test. Using the Wingate test, it has been reported by Inbar and Bar-Or (1986), that leg power in children has been shown to increase with age until the end of the third decade, whereas arm power reaches its highest value at the end of the second decade. It has been well documented that in youth from 10 to 15 years of age all their anaerobic parameters may be increased with training (Simon *et al*, 1981; Krahenbuhul and Pangrazi 1983, Inbar O, Bar-or O 1986).

The majority of the studies on anaerobic characteristics of children show that they are much less anaerobic, and consequently more aerobic, than their older counterparts, and even more so than the adult.

1.4 ANTHROPOMETRIC MEASUREMENTS

The anthropometric (physical characteristics) measures which describe morphology are well-established in sport science. "Morphology is the science of structure and form without regard to function. It is a fundamental law of biology, however, that form follows function and clearly there is a close relationship between the two" (Hawes and Sovak, 1992). These authors further state that "The implication of this statement is that morphology is dynamic in the sense that morphology is related to both the physiology and biomechanics of humans in motion and the recognition that masses, levers and forces are the 'cornerstone of human movement and their qualification is the foundation for building a more complete knowledge of human performance'" (Carter, 1985). This means that the youth will be inclined to choose a sport that allows the successful performance of that sport with his or her particular physical form. For example, a youth who is taller than his peers may choose basketball or volleyball where height is a distinct advantage, a lean, petite girl may choose gymnastics, a boy who is shorter than his peers with a high distribution of body fat may be a goalkeeper in ice hockey, a boy who has a large body structure will choose rugby or wrestling. This suggests that morphology has a direct relationship to performance. Scott (1991) quoted Ross, Marfall-Jones and Stirlling, (1982) who argued that an individual's somatotype is one of the best single biological identification tags, and Carter (1985) stresses the view that morphological factors play a limiting role in human performance. A youth's physical profile may limit performance in some sports and be an advantage in other sports.

Anthropometric measures will serve as a parameter to identify minimal and normal standards for hockey performance at the junior levels and can be considered in relation to elite male hockey players profiles which are known (Scott, 1991). This idea of morphological prototyping will "act as an indicator of changes occurring in a specific sport and hence serve as a model for guiding the development of those coming after; or as a tool for identifying individuals with exceptionally well-suited morphological characteristics for a given sport" (Hawes *et al* 1992). However, this must be considered in conjunction with the effects of growth and its implication during the growth spurt phases in youth. The failure to consider the growth factor may lead to serious mistakes (Woodman, 1985; Grisogono, 1991) and consequently frustration and failure (refer to section 1.3).

Jensen (1980) has identified length (height), mass (weight) and mass distribution as important structural attributes in sport performance.

Body fat ranges from 5 to 40% of a person's bodyweight (Grisogono, 1991). A youth with good muscle bulk may have a low percentage body fat but may look identical to one with low muscle bulk and high percentage of body fat and it is therefore inappropriate to measure only girth without measuring percentage body fat. Obesity is defined as a percentage of body fat of 30% of body weight or greater. There are numerous studies on the relationship between obesity and exercise in youth and this is beyond the scope of this review, suffice to say that in adolescence, lack of exercise or physical activity is a major cause of obesity (Grisogono, 1991).

It is generally accepted that a low percentage body fat in youth is best suited for most sporting activities, according to Grisogono (1991). A reasonable level of body fat is recommended for the adolescent girls as a very low percentage of body fat predispose to amenorrhoea or delayed menarche (Grisogono, 1991).

The percentage of body fat will be an important consideration in the type of sports a child chooses or a particular position in a sport that matches his or her physical characteristics. However, this characteristic may change and children should not be definitively assigned to a sport on the basis of body fat.

Six skinfolds sites were used to calculate percentage body fat, lean body mass and body fat using standard formulas. The estimation of body fat from skinfold measures was derived in a study by Durnin and Womersley (1974), on 481 men and women subjects ranging from the age of 16 to 72 years. Ross, Brown and, Howe (1982), used male and female students from three universities in Canada as controls for the MOGAP (Montreal Olympic Games Anthropometric Project) study where extensive anthropometric studies were done. The equation to determine percentage body fat was derived from this study. The validity of such estimation for children based on adult samples is unknown.

1.5 MEASUREMENTS OF PHYSIOLOGICAL PERFORMANCE CHARACTERISTICS

Physiological laboratory testing is one method of testing physical fitness. However, it has limitations in that it is not possible to simulate the physiological demands of the sport and therefore the practical value may be limited (MacDougal *et al*, 1991). The complete performance of a hockey player depends on the interplay of different factors of which physiological performance is only one. Tactical, psychological and technical factors are also important determinants. Physiological laboratory testing cannot by itself be used to predict hockey performance. An alternative is to utilise field tests which are often more valid because of their greater specificity (MacDougal *et al*, 1991). In addition, field testing enables large numbers to be tested regularly with minimal resources and costs.

No laboratory physiological tests were included in this study as the objective was to keep the tests simple so that they could be standardised and replicated in the future without difficulty and not be limited by lack of expensive laboratory equipment.

It is important for players and coaches to monitor the fitness levels, strengths and weaknesses. Physiological testing provides baseline data for individual training programme prescriptions. This feedback helps to evaluate the effectiveness of the training programmes and helps design programmes to enhance performance. It is also a means of detecting any changes in the general health status of the players. It is also increases the players awareness and understanding of his or her body in relation to the demands of hockey. Therefore, a set of normal standards of physical performance for young hockey players needs to be established.

A battery of physical performance test needs to be designed to evaluate the physical condition of players. The results of this would mean setting goals of physical condition appropriate for a particular age group, ideally for the biological or maturation age and not the traditional age group (refer to section 1.3).

The key elements of physical fitness in hockey are, speed (Reilly and Borrie, 1992), muscular endurance/aerobic capacity (Withers *et al*, 1977; Bale, 1986; Reilly and Borrie, 1992; Shergill, Singh and Tung, 1992; Boyle *et al*, 1994), anaerobic capacity/power (Withers *et al*, 1977; Bhanot and Sidhu, 1983; Sidhu *et al*, 1984; Bale, 1986; Reilly and Borrie, 1992; Boyle *et al*, 1994) strength (Scott, 1991; Shergill *et al*, 1992), flexibility (Scott, 1991), agility and skills.

Aerobic power

The energy required for normal activities of daily living are supplied aerobically as muscles use oxygen to release its fuel energy. The amount of oxygen consumed in a given time is called aerobic power. Aerobic power depends on the cardiac system (the heart to deliver the required amount of blood to the muscles), on the circulatory system (the delivery of blood to working muscles), and on the muscles' ability to utilise the oxygen to release energy. The more oxygen the muscle uses the more energy it releases. The maximal amount of oxygen uptake (VO_2max) is a measure of aerobic fitness. As this is largely dependent on the size of working muscle mass, body weight is taken into account and the results normalised, and expressed per kilogram of bodyweight.

Hockey involves short bursts (less than 30s) of high intense energy release followed by recover periods of lower intensity (Boyle *et al*, 1994). Although much of the performance energy in such sports may be derived from nonoxidative sources, the recovery between anaerobic bursts is an oxidative process that becomes more important with increased or more rapid repetition of the performance-recovery cycle. It is unlikely that the recovery process requires the high levels of maximal aerobic power that one associates with distance running, but it is logical to assume that an athlete with a high maximal aerobic power will tax nonoxidative sources less and recover at a more rapid rate from a given exercise than the less aerobically trained individual (MacDougal *et al*, 1991).

There are many methods used for testing aerobic power. Laboratory tests use sophisticated equipment to measure VO_2max directly and simpler tests are used on the field but are dependent on assumptions and extrapolations. VO_2max is one of the most popular laboratory test to determine oxygen consumption during aerobic exercise. The importance of this testing is that the subject should be compared to his or her previous results rather than against a standard for the group (MacDougall *et al*, 1991).

An indirect method to measure aerobic capacity is to measure heart rate (HR). Boyle *et al* (1994) state that it is well established that during submaximal exercise there is generally a linear relationship between oxygen uptake and HR (Astrand and Saltin,1961; Karvonen and Vuorimaa, 1988), therefore by continuously recording heart rates during a match and correlating this with HR and oxygen uptake measurements obtained during a laboratory-based incremental treadmill test, the field heart rates can be matched to the appropriate oxygen uptake. This enables the estimation of energy cost involved in the activity (Meir, Lowden and Davie, 1991). The monitoring of exercise by HR is limited to the specific range of exercise that is supported predominantly by aerobic metabolism i.e. the exercise must be of sufficient duration (usually more than 3 minutes) to allow HR to increase in proportion to intensity and must be of a consistent intensity for the it to be declared aerobic (MacDougall, 1991).

There are three field tests that can be used to measure aerobic fitness, winder, bleep and 3000m run. The first two correlate very well in simulating conditions of play in hockey as the player is tested running for short distances with changes in direction. This is done continuously during the duration of the test. The test results should not be compared with each other, but rather the same test in and out of season.

These tests, test the players' efficiency to perform maximal or sub-maximal exercises for the duration of the game lasting 70 minutes and the ability to recover from these exercises.

Anaerobic power

The muscular effort in short sprints, as in hockey, derives its energy from non-oxygen sources, referred to as anaerobic. It is the rate of work done without the use of oxygen. The anaerobic capacity is the person's total capability for a single sustained bout of anaerobic work. The source of fuel in anaerobic work refers to the use of stored creatine phosphates and glycogen as a source of immediate energy. As the stores are limited anaerobic activities can only be sustained for very short periods lasting for about 30 seconds and thereafter the exercise becomes increasingly aerobic until about 2 minutes when it becomes totally aerobic, provided that the run is sub-maximal.

The duration of anaerobic power energy activities are classified as short term (up to 30s), intermediate (30-60s) and long term (1-2 min). The anaerobic energy demands during these periods need to be tested to determine the ability of the player to perform during such activities.

Sophisticated laboratory tests can be performed to test anaerobic capacity or alternatively, simple related field tests can be used e.g. the number of push-ups in a given time. The laboratory test includes the measurement of oxygen debt incurred during the anaerobic phase of the exercise i.e. the post exercise 'extra' oxygen (oxygen debt) consumed, above the amount needed to sustain the resting metabolism, measured for ten minutes. The higher the oxygen debt the better the anaerobic capacity. Another method is to measure the levels of blood lactate. At higher intensities of exercises the concentration of lactate increases in the blood and this is indicative of the anaerobic source of fuel. Therefore the concentration of blood lactate in the blood indicates the intensity at which the exercises are being performed.

If the anaerobic power system is underdeveloped, fatigue sets in more rapidly and limits performance. Training needs to be instituted to increase the capacity of the anaerobic power system.

Speed and acceleration

Speed and acceleration are important for good sprint performance, which is essential in hockey, however, the test must be applicable to hockey, e.g. a 40m sprint or a variation with change in directions to simulate conditions on the field. These are short runs done with maximum effort with rapid acceleration. A game of hockey requires short duration maximal or sub-maximal sprints to be regularly repeated over an extended period of time (70 minutes). Performance tests of repeated sprint ability (RSA) are not well established despite their specificity for measuring the fitness of team sport players (Fitzsimmons, Dawson, Ward and Wilkinson, 1991). Fitzsimmons *et al* (1991) developed and initially tested the reliability of running (6 x 40m efforts, departing every 30s) in amateur male team sport players and in sprint cyclists (6 x 6s efforts, departing every 30s). They found that both cycling and running RSA tests were found to have suitable test-retest reliability. The degree of association between the two modes of RSA test was then assessed in male field hockey players. A multiple 40m sprint test would therefore be appropriate to assess for hockey fitness.

The quality of speed performance is not only determined by anaerobic capacity but also by technique, strength and neurogenic factors. The neurogenic factors refer to the neural pathways having to 'learn' to adapt to changes in speed when the player suddenly accelerates. During a game, players need to respond to visual and auditory stimuli i.e. developing a reaction time which is clearly related to the function of the nervous system. The total improvement in speed does not exceed 18-20 % and mainly occurs at an early age, usually between 6-13 years, after this only small progress can be realised with considerable effort and by emphasising strength training (Vecchiet *et al*, 1992).

Speed endurance and agility

The speed endurance and agility test is a form of intermediate anaerobic performance test which will test the total work output during maximal exercise lasting 30s e.g. a shuttle run for 30s. This tests the ability to resist fatigue whilst performing high speed running. The test is specific to the type of activity that one might expect in a game situation and agility will affect the speed at which the task is carried out.

Strength and power

Muscle strength is an important predictor for successful sports' performance in youth. Muscle strength is the ability of the muscle to generate force, which is directly proportional to the cross-sectional area (girth) of the muscle. Strength training results in the increase of the muscle bulk (hypertrophy). An important predictor in sports performance is muscle power, which is the combination of force and speed with which the muscle may generate it. Strength increases naturally with growth, which may peak during the adolescent growth spurts in girls, and a year after the growth spurts in boys (Potthast and Klimt, 1988).

There is a relationship between strength and speed. The degree of correlation between strength and speed performance depends on how strength is measured. The correlation between increases in strength through training and improvements in speed performance depends on the degree to which the training is velocity specific.

Hockey is game which demands short explosive runs. A great deal of accelerating and thrusting off with the legs in sudden bursts of speed or in rapid changes in direction is required. Therefore a measure of the player's leg strength is appropriate if measured at high speed.

A valuable test to measure power is the ability to perform an explosive jump e.g. the standing broad jump which is generally accepted as a measure of leg power. The major muscle groups that are being used are the quadriceps and calves. The explosive jump or the broad jump, may not be sport-specific to hockey. It has however, been recommended by most investigators of physiological testing as a fairly reliable indicator of muscle power of the lower limbs (MacDougal *et al*, 1991). This test is very specific to the large muscle groups in the legs, the results of which would reflect on strength and power of the lower limbs. This test would be used to evaluate the effectiveness of a training programme being followed as well as to determine a strength/power fitness profile of the player, which will allow individual strengths and weaknesses to be identified.

Since strength and power tests need to be sport specific the grip strength test measures an important component in hockey i.e. the strength to hold a hockey stick and while running to hit the ball with accuracy and power. A standard dynamometer should be used to measure grip strength.

Hockey demands dribbling the ball with a hockey stick in a crouched position. The muscle groups of the arms and the upper body have to be strong to manipulate the stick and ball. The muscular strength of the arms and the upper body must also be tested.

Muscular Endurance

Muscular endurance refers to the ability of the muscles to 'endure' repeated work loads over a period of time, as in hockey (70 minutes) without fatigue.

The test should measure muscular endurance, fatigue being the limit to endurance. The tests are very specific and simple. Push-ups for the males and modified push-ups for the females.

Sit-ups test the abdominal muscles which are important because most of the body control is at the mid section and it affects all skills, marking, sprinting, agility and continual running will be affected.

Flexibility

Measurement of joint range is by means of a goniometer, which measures the range of movement in a joint in degrees, or by specific positions, e.g. sit and reach to measure lower back and hamstring flexibility (Feiring & Derscheid, 1989).

Flexibility is an important component of sport performance, injury prevention and rehabilitation. Poor flexibility will increase the risk of injury, reduce the range of movement, impair skilled movement, prolong recovery and reduce speed and agility (Grisogono, 1991; Mac Dougall *et al* ,1991).

An evaluation of flexibility helps determine:

a) if the players can perform the skills required with minimal stress on the muscle-tendon tissues

b) improvements or deterioration in flexibility with training and activity.

c) problem areas that maybe associated with poor performance of a skill or with possible risk of injury.

In this study a simple "sit and reach" test designed originally by Wells and Dillon (1952) which was reported to be a valid test for leg and back flexibility, has been used as a measure of flexibility. However, MacDougall *et al* (1991) reported that this test does not provide valid measures of flexibility because of the many uncontrolled variables. In many cases, the measurements are meaningless because the external zero position can be arbitrarily chosen. The movements are combination of movements at several joints, thus making it difficult to determine what is being measured. Leger and Cantin (1983) showed that the sit and reach test were not interchangeable and thus were not measuring the same variables. The anthropometrics of the individual can affect the measurement, thus making between-subject comparisons difficult (Wear, 1963; Broer and Galles, 1985).

It should be evident that these type of tests are not valuable for detecting changes in elite athletic groups but at best serve as gross approximations of flexibility. This test should therefore be regarded as a relative indicator flexibility and in this study a 'normal' standard required for hockey will be established. The test is simple so that it can be performed anywhere without difficulty.

1.6 SKILLS TEST

All too often, hockey coaches may find it convenient to leave out hockey skills from field tests in evaluating fitness of players. In such cases sprint times over 50m (Reilly and Bretherton, 1986) and the 20m shuttle run test to predict VO_2max are examples of feasible tests. It should be recognised that these are dependent on motivational compliance of subjects and are not true indicators of physiological limits of players (Reilly and Borrie, 1992).

Hockey-specific skills are important in successful hockey performance. A test of hockey-specific skills should be included in a hockey fitness assessment which will test ball control, hand-eye co-ordination, strength, speed and agility whilst using a hockey stick. A number of tests, similar to the ones referred to (in section 1.2) above have been used in the current study. For detailed description of the tests refer to the section on methods below.

In summary, in designing the testing programme, the following were considered:

a) the variables that were tested were relevant to hockey.

b) the tests were valid and reliable - it had to measure what it claims to measure, the results must be consistent and reproducible.

c) the tests were hockey specific.

d) the test be administered in a controlled environment - clear instructions, warm-ups, recovery times, on the same surface, in the same order, at the same venue, at the same time of day, with same administrators.

2. MATERIAL AND METHODS

2.1 SUBJECTS

In this study junior provincial players from the KwaZulu Natal Hockey Association Academy were studied and measurements made on these players. The tests were performed at the KZN Hockey Association Academy at Queensmead, Durban by sports administrators and coaches. Before the commencement of the tests all the players signed an informed consent form. The players were members of their respective provincial teams according to the five different age groups (under 13, 14, 16, 18 and 21 years) for both the boys and girls. Measurements were made at the start of the season, in April 1996, and at the end of season, October 1996.

However, because of the timing of the end of season testing many of the players were not available and all the tests were done on all the players. Therefore, the data available from April is used for descriptive norms and early and end season comparisons are made only in those players who underwent both set of tests. The following table indicates the number of players studied in the different age and sex groups. (Table 1).

Table 1: Number of subjects studied pre and end season.

Boys

	Under 13	14	16	18	21	TOTAL
Pre-season	11	18	38	36	13	116
End-season	18	28	24	0	0	70

Girls

	Under 13	14	16	18	21	TOTAL
Pre-season	11	27	51	41	22	152
End-season	14	23	27	28	0	92

2. 2. TEST ADMINISTRATION

PRE-TEST, TEST AND SUBJECT PREPARATION

To standardise the tests, they were performed according to the method laid down, on the same surface, in the same order, at the same venue, at the same time of day with the same test administrators and administered on three separate days before rather than after a training session.

There was no training in the 24 hrs prior to the testing, and tests were performed prior to training. No food, cigarettes or beverages containing alcohol or caffeine were consumed two hours prior to testing

Day 1: Sequence: sit-ups, push ups and broad jump.

Day 2: Height, weight, flexibility, body composition, winder / bleep test.

Day 3: (All skills tests) Bounce left and right, reverse push, front push, hit forward, yard and tuck run.

2.3. TEST DESCRIPTIONS

ANTHROPOMETRIC MEASURES

The anthropometric measurements taken were height, weight and six skinfold measures using a Harpenden skinfold calliper.

i) Height was measured from the highest point on the head in the median sagittal plane (Vertex) to the soles of the feet with a portable Harpenden stadiometer. The subject stood erect and barefoot with heels in contact with each other, buttocks, upper back and rear of head in contact with the vertical section of the stadiometer. The upper limbs were resting at the sides and the head was in the horizontal plane. Upon taking the measurement the subject inhaled deeply and stretched up to the fullest extent. Care was taken to ensure that the heels were not raised.

ii) Weight was measured on a calibrated scale. The subject was bare foot, the boys wore only shorts and the girls shorts and a 't' shirt.

iii) Percentage body fat. All skinfolds were taken on the right side of all subjects apart from the abdominal skinfold reading which was taken on the left side of the umbilicus. All skinfold measurement sites were marked with a cross on the subject. A fold of skin and subcutaneous tissue was picked up firmly between the thumb and forefinger 1-2cm above the marked cross and pulled away from the underlying muscle.

The jaws of the calliper were placed on either side of the cross below the fingers at a depth of approximately 1cm. The surface of the calliper jaws were held parallel to the plane of the skinfold. The skinfold was held firmly throughout the application of the calliper and the reading was taken once the needle became steady. The subject stood erect for all the skinfold readings with the exception of the calf reading which was done while the subject was seated. The site for each skinfold is as follows:

a) Triceps: this site was located as the midpoint between the acromion process and the radial head.

b) Subscapular: this site was located just below the inferior angle of the scapular. It was measured in an oblique plane descending laterally (outwards) and downwards at an angle 45° to the horizontal.

c) Suprailiac: this was located 5cm above the anterior superior iliac spine. It was measured with a fold descending: medially (inwards) and downwards at an angle of 45° to the horizontal.

d) Abdominal: the abdominal site was located 5cm to the left of the umbilicus at the same level.

e) Mid-thigh: with the subject standing, the midpoint between the tip of the greater trochanter and tibial plateau was located. In line with this point the skinfold site was marked at the centre of the anterior surface of the thigh.

f) Calf: was measured at the centre of the calf (leg) at the marked level of the greatest calf girth. The subject was seated with the knee flexed in 90°.

The percentage body fat was calculated using the MOGAP (Montreal Olympic Games Anthropological Project) study equation (Carter *et al*, 1982) which is the sum of the six skinfolds multiplied by 0,1458, added to 3,580. The body fat and lean body mass was calculated with standard equations using the percentage body fat.

PHYSIOLOGICAL TESTS

These tests were used to determine the fitness levels of the players in the different physiological components as described previously in section 1.5, viz. aerobic power, strength power, speed, flexibility and endurance. Table 2 describes the different components and the respective tests.

Aerobic Power

i) Winder (Double)

This test was used to estimate aerobic speed endurance. Participants ran a pyramid course. That is, to 22m and back, 50m and back, 75m and back, 100m and back. They repeated the 100m and then ran 75m and back, 50m and back and finally the 22m and back. This completed one winder. The break between the 1st and 2nd winder was the following, 3 min for men, 3.5 min for girls and 4 min for all those under the age of 18 years. Time to the nearest 0.1 of a second was recorded.

Table 2: Fitness component and the respective tests.

FITNESS COMPONENT	**TESTS**
AEROBIC POWER	WINDER and BLEEP TEST
STRENGTH AND POWER	BROAD JUMP
MUSCULAR ENDURANCE	PUSH-UPS AND SIT-UPS
FLEXIBILITY	SIT AND REACH

ii) Bleep test

This test was used to determine aerobic power. The test was performed on the astroturf surface with beacons set 20m apart. A stop watch, whistle, multistage tape and cassette player were used.

The subjects ran to and fro (a shuttle run) along a 20m measured track, keeping up with a series of bleeps on the cassette. The timing bleeps begin slowly, but became progressively faster, so that it became harder and harder to keep up the required speed. The subjects always placed one foot either on or behind that 20m mark at the end of each shuttle. The runner stopped when he/she could no longer maintain the set pace. If the subject failed to reach the end of a shuttle before the bleep, they were allowed 2 or 3 further shuttles to attempt to regain the required pace before being withdrawn and instructed to stop the test.

The score was calculated using the tables provided with the audio cassette tape.

Strength Power

i) Broad Jump

This test was used to correlate sprinting and acceleration power, and is the ability to perform an explosive jump. The muscle groups of the lower limbs, the quadriceps and calves are tested.

Subjects stood with both big toes on a marked line. Bending their knees they jumped forward as far as possible. They were allowed to extend their arms as far back/forward as possible. Both feet had to take-off and land together.

The distance was measured from the take-off point to the closest heel mark after jumping. Three attempts were made and the average recorded.

Upper body muscular endurance tests

This is the ability to perform local muscular activity continuously. The purpose of this test is to test muscular endurance of the upper body.

i) Push up (boys)

Strict adherence to the method laid down was essential. The subject's hands were in line with the shoulders and backs were kept straight throughout the test. The participant lowered his body until the chest touched the clenched fist of the counter, who held their fist in line with the sternum. The arms were then immediately straightened. Only the hands and feet were in contact with the floor. If the subject stopped at any time during the test the knees were not allowed to touch the floor. If they did not comply with this, the test was considered to be void.

No score was given if the above conditions were not met or the form of the push up deteriorated. The test continued for one minute without rest and the completed repetitions were counted.

ii) Push up (girls)

Strict adherence to the method laid down was essential. The subject's knees were bent at right angles and the hands were in line with the shoulders and backs were kept straight throughout the test. The participant lowered her body until the chest touched the clenched fist of the counter, who held her fist in line with the sternum. The arms were then immediately straightened. Only the hands, knees and feet were in contact with the floor. If the subject stopped at any time during the test they had to rest in the starting position.

No score was given if the above conditions were not met or the form of the push up deteriorated. The test continued for one minute without rest and the completed repetitions were counted.

Abdominal muscle endurance

This is the ability to perform local abdominal muscular activity continuously. This test was used to measure muscular strength and endurance of the mid-section.

i) Sit-up

The participants had to lie on their backs with their knees bent at 90°, with the hands straight out in front resting on the thighs. The ankles were not held by the counter. On the "go" the participant pulled up into a 30° crunch position such that the hands slid to on top of the knees and then returned to the lying position. The shoulder blades had to touch the ground in the supine position. This counted as one repetition.

No score was given if the condition was not met or the form of the sit-up deteriorated; there were no half counts.

The test ran for one minute. A score of 1 was given for each correctly executed sit-up.

Flexibility

This is the range of movement at the hip joint. The purpose of this test was to assess flexibility of the lower back and hamstrings.

i) Sit and Reach

A measuring tape and a flexibility box were used the ruler was set at 37 cm = 0.

The subject removed their shoes and sat with their heels on the start line with knees extended and their feet a shoulder's width apart. The arms were extended forward with palms facing down. The subject reached forward with both hands and held this position for 10 seconds. The knees had to stay in contact with the ground and were not allowed to be raised. The position of maximum reach was recorded. The participants were allowed the best of 3 attempts. A warm up routine was performed before the test was taken.

SKILLS TESTS

b) The skills components tested are as follows:

Table 3: Skills component and the respective tests.

SKILLS COMPONENT	TESTS
BALL CONTROL	YARD, REVERSE, FRONT, HIT
AGILITY STAMINA RUNNING WITH STICK AND BALL	TUCK RUN
HAND EYE CORODINATION, STRENGTH	BOUNCE TEST

i) Bounce Test

This test was done holding the stick at the top end with one hand and the ball was bounced on the stick. The right hand was tested first and then the left, for a maximum of two minutes or until fatigue. Children U14 held the stick in the middle. The ball was bounced continuously without the ball dropping to the floor, the counting stopped as soon as the ball fell to the ground.

The subjects had three tests with both the left and right hands and the average was recorded for each hand.

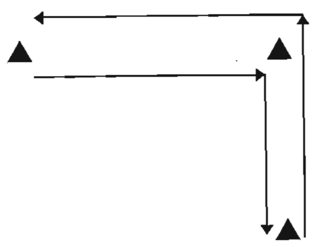
ii) Tuck run

The players were required to dribble a ball around beacons set out as in the diagram below for 1 min.

The player was told when the time was over and his/her position was noted.

Two attempts were recorded and averaged The score was the count of the total number of beacons passed. The time was taken once the player was ready waiting at the start for one minute after receiving the signal "Ready" "Go".

Figure1: The Tuck run



iii) Yard

The players were required to drag the ball from left to right across a line of 92cm drawn on the ground. (See diagram below). This was repeated continuously from side to side for 1 minute.

Two attempts were recorded and averaged. The player was told when the time was over and each time the ball reached the one end a score of 1 was given.

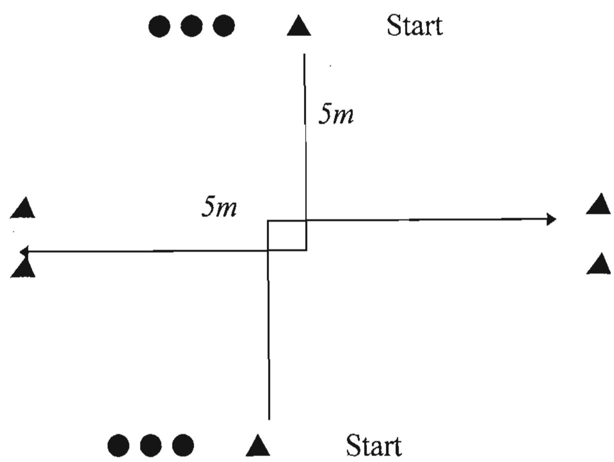
Figure2: The Yard

iv) Reverse Push

This test was done with the player dribbling the ball to a beacon 5m from the start, turning around the beacon and then attempting to hit the ball between the beacons (see diagram below). After the first attempt the players went onto the second start and repeated the above. The player had 6 balls to use, 3 on each side.

The player was timed for all 6 attempts and a score of 1 was given if the ball passed between the beacons.

Figure 3: The Reverse Push

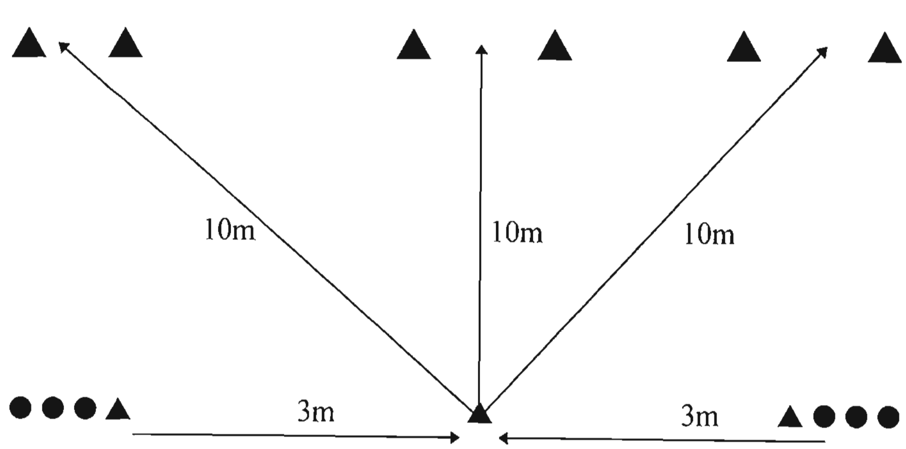


v) Forward Push

The players dribbled the ball from the start across a 3 metre line to a beacon. They turned around at the beacon and then hit the ball at an angle to a set of two beacons 10metres away, they attempted to get the ball between the beacons. The player then ran to the other starting point and repeated the dribble to the middle beacon and hit the ball at the second set of two beacons. This was repeated until all 6 balls were used up with 2 attempts each for each set of two beacons (see diagram below).

The time taken to finish all 6 hits were recorded and a score of 1 was given for each hit between the beacons.

Figure 4: The Forward Push

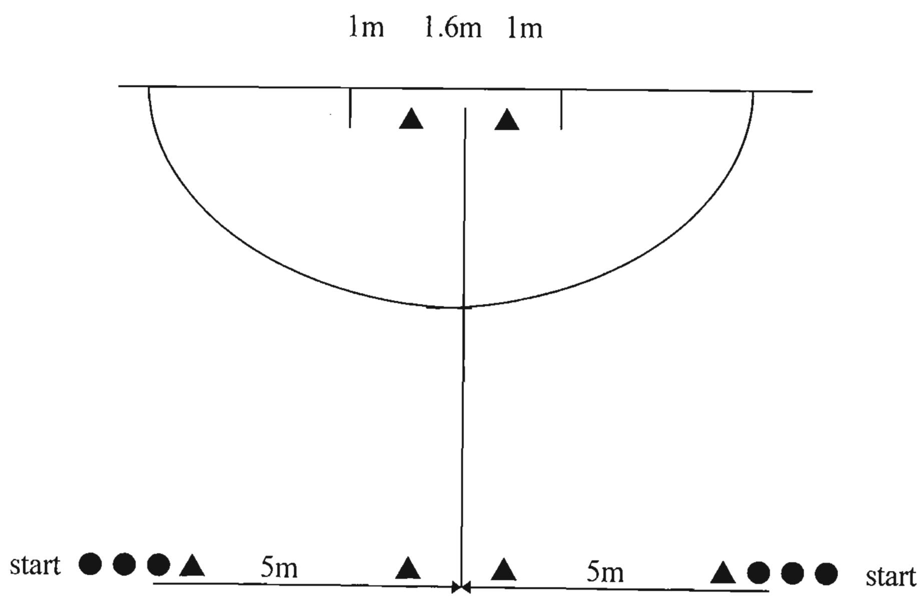


vi) Hit Forward

The player started at the 25m line from the goals. The player dribbled the ball 5m from the start (see diagram below) towards the centre and turned at 90° between the two beacons and hit the ball towards the two beacons between the goals. The two beacons were placed 1 metre from each goal post. They repeated this from the opposite start until all 6 attempts were made.

The time taken to complete all 6 attempts were recorded and 2 points were given if they scored between the beacon and the goal (1m) (more difficult) and 1 point if they scored between the two beacons (1.6m).

Figure5: The Hit Forward



2.4 STATISTICS

The data was recorded for each variable (where the data was available) for each of the five age groups, separately for boys and girls and for pre and post season testing. Standard descriptive statistical methods were used. The mean and standard deviation was calculated for each variable for each group. An analysis of variance (ANOVA) was used to examine the differences between the groups across all the variables, P values were computed and statistical significance was set at $P<0.05$. No post-hoc tests were done to determine where the differences lay between groups because of the relatively small numbers in some of the groups, e.g. in Table 6 the number of subjects tested ranged from 2 to 12.

Each of the groups were divided into 3 field positions, the attacking players (forwards and mid-field players), defending players (the backs) and goalkeepers. However, comparisons were only made between attack and defence as the number of goalkeepers in each group were very small. The attack versus defence comparisons were made using an unpaired t test for each variable in each group in both pre and end season results to determine if there were any positional differences in physical characteristics, physiological or skills performance.

Paired t tests were done to determine if there were any changes in the variables of the players who had been tested in both pre and end season. Paired t-tests were used to compare players who were tested at the beginning and at the end of the season to determine any changes observed with training during the season and or the effect of growth. The results are set out in tables 8 and 9.

The data in the pre season has the largest set of variables tested whereas in the end-season weight was not taken and therefore no values for body fat, lean body mass and percentage body fat are presented. This has been a limitation in this study as it would have been preferable to deduce the norms from the end of season results. The data at the beginning of season provides the first set of norms and the data are presented in tables 4-5 with means, standard deviations, numbers tested and P values for all groups. The number of subjects tested has been recorded in each table and varied from 11 in the under 13's to 41 in the under 18's.

The physiological test of sit-ups, push-ups, flexibility and broad jump were recorded in most of the groups. The winder and bleep tests were not performed in all the groups. This is a further limitation in this study as it would have been important to establish a norm for aerobic capacity for all the groups.

The skills tests have been comprehensively recorded in all the groups, pre and end season.

In each group a comparison was made between attacking and defending players for each of the variables in both pre and end season and are presented in tables 6-7.

3. RESULTS and DISCUSSION

This is a descriptive study and therefore the results will be presented and discussed at the same time. This study has provided descriptive statistics for anthropometric measures (height, weight, percentage body fat, lean body mass and body fat), physiological performance (sit-ups, push-ups, broad jump, winder and bleep) and skills tests (bounce, yard, tuck, reverse push, front push and hit forward) for the establishment of normative data for five age groups from under 13 years to under 21years in both male and female junior hockey players.

3.1 BASIC NORMS

BOYS

ANTHROPOMETRY

There was a significant change in height with age ($P<0.001$) which was expected as a result of growth. The literature reflects that the growth spurt in the boys occurs between 12-14 years and lasts about 2 years. In the current study the mean height (table 4) reflects that the largest increase in height (9cm) was between the age groups U13 and U14. The U21 had a mean height of 1.81m. This is taller than the South African elite male players studied by Scott (1991) who had a mean height of 1.76m, and that of the Indian Tokyo Olympic team (Hirata, 1966) who had a mean height of 1.73m.

The weight, lean body mass and body fat results reflected a difference in body composition between the groups ($P<0.001$, $P<0.001$ and $P<0.05$ respectively), but the difference in percentage body fat was not significantly different between the age groups. The mean U21 weight was of 67.8kg, whereas the mean body weight was 75.2kg in the South African elite male players Scott (1991). In this study the percentage body fat ranged from 7-9%, which is much lower than the expected norm of 12-14% for boys of 17 years (Grisogono, 1991). Scott (1991) reported a percentage body fat of 11.1% in male hockey players. It is possible that the youth are undergoing body weight changes and have not reached their adult values. It must be noted that the skinfold measures are operator dependent and therefore there could be an inter-operator difference in the measurements.

Table 4: Mean anthropometric, physiological and skill tests of age group hockey players, based on pre season tests (boys).

	U13			U14			U16			U18			U21			
	N	MEAN	STDEV	N	MEAN	STDEV	N	MEAN	STDEV	N	MEAN	STDEV	N	MEAN	STDEV	P VALUE
ANTHROPOMETRIC																
Height (m)	11	1.50	±0.08	18	1.59	±0.09	38	1.67	±0.09	36	1.73	±0.08	13	1.81	±0.08	P<0,001
Weight (kg)				18	49.56	±9.38	38	56.26	±9.87	36	65.06	±8.36	13	67.77	±10.72	P<0,001
% BF				18	7.71	±1.40	38	8.54	±2.41	32	8.01	±1.49				n/s
LBM (kg)				18	45.64	±8.44	38	51.29	±8.35	28	60.67	±6.90				P<0,001
Body Fat (kg)				18	3.86	±1.19	38	4.93	±2.11	28	5.37	±1.48				P<0.05
PHYSIOLOGICAL																
Situps	11	45.36	±5.46	18	39.50	±6.72	38	39.92	±9.69	41	40.27	±7.49	13	49.38	±9.27	P<0.01
Pushups	11	59.82	±8.34	18	31.56	±15.27	38	41.97	±13.66	40	41.18	±8.36	13	40.38	±8.63	P<0,001
Flex	11	40.27	±4.31	17	43.97	±6.37	30	42.98	±5.94	41	45.90	±6.57	13	47.65	±10.76	P<0.05
B/Jump	11	1.78	±0.11	18	1.92	±0.18	37	2.02	±0.18	39	2.25	±0.21	13	2.26	±0.36	P<0,001
SKILLS																
Bounce R							37	52.11	±26.09	32	33.56	±16.45				P<0,001
Bounce L							37	18.43	±9.27	32	14.13	±7.82				P<0.05
Yard							38	100.79	±23.92	33	107.18	±20.98				n/s
Tuck							39	32.03	±4.35	35	31.11	±3.93				n/s
Rev Push T							37	25.05	±3.14	35	22.03	±3.25				P<0,001
Rev Push S							34	2.32	±1.07	35	2.43	±1.27				n/s
Front Push T							37	27.35	±2.57	35	23.78	±3.87				P<0,001
Front Push S							37	2.78	±1.25	35	2.51	±1.29				n/s
Hit Forw T							37	32.49	±3.62	35	28.48	±4.51				P<0,001
Hit Forw S							37	5.08	±2.41	35	4.26	±1.87				n/s

PHYSIOLOGICAL TESTS

In table 4, the results reflect a distinct difference between the age groups in sit-ups, push-up, flexibility and broad jump ($P<0.01$, $P<0.001$, $P<0.05$ and $P< 0.001$ respectively). The mean values for the U13 in the sit-ups (45) and push-ups (60) were higher than in the rest of the age groups except in the U21 where the sit-ups (49) were higher than all the groups. This suggests a decline in muscular strength, whereas the literature suggests that there is a gradual increase in strength with age (Grisogono, 1991). It is possible that the increase in body weight may have affected the strength : weight ratio i.e. the increase in strength has not been in proportion to the increase in weight. It appears that the U13 players have stronger upper bodies relative to bodyweight. However, it is noted that the sample size of 11 in the U13 is smaller than the other groups which varied between 17 and 41, and the results may not be representative. Another possibility for this difference is that the U13 may have been more motivated and enthusiastic and therefore performed better.

The results of the flexibility test reflect a difference between the age groups ($P <0.05$). The mean value improved from 40.3 cm in the U13 to 47.6 cm in the U21, whereas previous studies reported a decrease with age (O'Neil and Micheli, 1988). This improvement in the flexibility values with age may be as a result of flexibility exercises being included in the training programme. It is of interest that there is a strong relationship between flexibility as measured by this test and height r = 0.94 (P<0.02).

Differences in broad jump results were highly significant between the ages (P<0.001). The mean values improved throughout the age groups from U13 to U21 (from 1.77m to 2.26m). This probably reflects the increase in height with age. Pearson's correlation co-efficient for broad jump and height is r = 0.97 (P<0.007).

SKILL TESTS

Skills test were only undertaken by the U16 and U18 groups. In table 4, the results of the yard and tuck reveal no difference between the ages. In the bounce test, to the right and left, the U16 performed better than the U18 (P<0.001 and P<0.05 respectively). In the reverse, forward and hit tests there is a significant difference between the groups for the time taken to score in these tests (P< 0.001 for all) but the score results are not significantly different. However, it is noted that U18 took longer and scored more in the front and hit tests. There appears to be a wide variation between the groups with no distinct pattern. For example, the U18 performed poorly compared to the U16 in the front push and forward hit. They took less time but scored less than the U16 whereas, in the yard they performed better than the U16. Therefore, there appears to be no consistent difference in the ball skills between the two groups. It is expected that the older groups might perform better than the younger groups because of their experience and training.

GIRLS

ANTHROPOMETRY

There was a significant effect of age on age group height (P<0.001) this was expected as a result of growth. In the current study (table 5) the mean heights for the U16 and U18 (1.63 m) was the same with the U21 group 1 cm taller (1.64m). The above values are comparable to adult hockey players whose mean values range from 1.62 to 1.65m. The largest increase in height (5cm) was between the U13 and U14 with the difference between the U14 and U21 being 6cm. The literature reflects that the growth spurt in girls occurs between 10-12 years and lasts about 2 years. It is therefore possible that the girls who were 16 years and over had passed the growth spurt phase of development and had reached their adult height, especially the girls.

Table 5: Mean anthropometric, physiological and skill test of age group hockey players based on pre season (girls).

	U13			U14			U16			U18			U21			
	N	MEAN	STDEV	N	MEAN	STDEV	N	MEAN	STDEV	N	MEAN	STDEV	N	MEAN	STDEV	P VALUE
ANTHROPOMETRIC																
Height (m)	11	1.54	± 0.08	27	1.58	± 0.07	51	1.63	± 0.06	41	1.63	± 0.06	23	1.64	± 0.07	P<0.001
Weight (kg)				27	51.91	± 7.58	51	54.73	± 7.77	41	55.88	± 7.68	23	61.87	± 11.83	P<0.001
% BF				27	15.48	± 3.45	48	16.90	± 3.32	42	16.64	± 3.47	19	17.34	± 2.90	n/s
LBM (kg)				27	43.82	± 5.55	48	45.23	± 5.56	40	46.26	± 5.49	17	50.17	± 5.20	P<0.05
Body Fat (kg)				27	8.05	± 2.98	48	9.35	± 2.88	39	9.34	± 2.99	18	10.59	± 2.95	P<0.05
PHYSIOLOGICAL																
Situps	11	34.45	± 4.76	27	35.85	± 7.85	51	33.55	± 6.50	39	37.36	± 8.33	24	44.17	± 14.53	P<0.001
Pushups	11	53.64	± 11.34	25	46.96	± 11.62	51	34.25	± 8.01	40	40.05	± 9.41	24	35.13	± 12.13	P<0.001
Flex	11	47.27	± 4.47	26	47.47	± 7.28										n/s
B/Jump	11	1.71	± 0.15	27	1.77	± 0.20	51	1.71	± 0.16	41	1.77	± 0.14	24	1.83	± 0.22	n/s
Winder				19	4.09	± 0.23	31	4.17	± 0.09	27	4.10	± 0.25	18	4.06	± 0.29	n/s
Bleep				36	7.48	± 1.54	39	7.62	± 1.57							n/s
SKILLS																
Bounce R							52	16.71	± 8.27	28	10.93	± 3.99	17	15.53	± 6.23	P<0.001
Bounce L							52	11.12	± 7.18	28	6.00	± 2.51	17	7.53	± 3.91	P<0.001
Yard							44	106.91	± 24.32	28	111.50	± 25.16	17	134.41	± 30.21	P<0.05
Tuck							53	27.42	± 5.46	37	27.54	± 4.39	18	34.56	± 7.19	P<0.001
Rev Push T							51	29.22	± 4.40	37	26.54	± 3.67	18	27.52	± 6.38	P<0.05
Rev Push S							50	2.16	± 1.22	37	1.84	± 0.96	18	2.83	± 1.29	P<0.05
Front Push T							52	28.19	± 4.61	37	27.76	± 3.71	18	26.20	± 5.77	n/s
Front Push S							52	2.13	± 1.39	37	2.03	± 1.21	18	3.11	± 1.32	P<0.05
Hit Forw T							52	34.27	± 4.54	36	33.55	± 3.85	18	30.96	± 5.27	P<0.05
Hit Forw S							52	4.06	± 2.10	36	4.44	± 1.99	18	4.11	± 1.94	n/s

The weight, lean body mass and body fat results reflected a distinct difference in body composition between the groups (P<0.001, P<0.05 and P<0.05 respectively). The mean body weight ranged from 51.9kg (U14) to 61.9kg (U21), which compares favourably to the adult values which range from 58kg to 62.9kg (Reilly and Borrie, 1992). Only the percentage body fat was not significantly different between groups. The percentage body fat of U13 (15.48%) to U21 (17.34%) are within the normal range (Grisogono, 1991). Reilly and Secher (1990), reported that the range for female players is between 16 to 26%. The literature also indicates that following the growth spurt (10-12 years), girls tend to produce relatively more fat than boys, increasing to a mean body fat of 25% at 17 years (Grisogono, 1991). All the values show an increase between the age groups, reflecting the change in body weight with age and consequently % body fat, lean body mass and body fat.

PHYSIOLOGICAL TESTS

In table 5, the results reflect a significant difference between the groups in the sit-ups and push-ups (P <0.001). The mean sit-up values in the U13, U14, U16 and U18 were similar, whereas, the U21 were significantly higher. The mean push-up values showed that the U13 (54) performed better than the other groups with the U21 only managing 35. This reflects a decline in muscular strength, whereas the literature suggests that there is a gradual increase in strength with age (Grisogono, 1991). It is possible that the increase in body weight may have affected the strength : weight ratio i.e. the increase in strength has not been in proportion to the increase in weight or that the training was ineffective. It appears that the U13 players have stronger upper bodies. However, it is possible that the small sample size of 11 in the U13, when compared to the other groups which varied between 24 and 51, may have been resulted in skewed data. This argument is supported by the fact that the mean values of the sit-ups and broad jump showed no significant improvement between the age groups except for the U21. Another possibility for this difference is that the U13 were more motivated and enthusiastic and performed better. It is interesting to note that the results in the boys were similar in that the U13 performed better than the other age groups except for the U21. The improvement in the U21 could be as a result of improved training, technique or co-ordination.

The results of the flexibility test was not statistically significant different between the U13 and U14.

The mean value for the broad jump showed no significant variation. It is expected that general body strength improves with age and or with training but in this particular group the training was either ineffective or strength did not improve proportionally with growth.

Both the winder and bleep tests showed no significant difference between the two age groups tested (U16 and U18). This suggests that there is little difference in the aerobic capacities of these two age groups. The literature suggests that the trainability of children as regards aerobic capacity is controversial. Some studies have indicated little or no training effect (Daniels *et al*, 1976) and others reported significant changes (Kobayshi *et al*, 1978). Grisogono (1991) suggests that training programmes do increase the aerobic power but no specific year can be identified in which the greatest benefit occurs. In the current study very few winder tests were performed and therefore the results are not representative of young hockey players.

SKILLS TEST

In table 5, in almost all the skills tests the results are statistically significant indicating the differences between the age groups (P< 0.05 or P<0.001). However, in comparing the mean values of all the tests between the age groups no distinct pattern emerges, in some cases the U16 performed better than the U18 and vice versa, and the U21 performed better in some instances than the other 2 groups. Therefore, there appears to be no consistent difference in the ball skills between these groups. From this it could be inferred that the ball skills in the older groups are no better than the younger groups which is contrary to what is expected or that the skills tests are not appropriate and require additional learned motor skills to compare them. It may also indicate that the tests are not refined enough to demonstrate improvement.

3.2 ATTACK vs DEFENCE COMPARISON

BOYS

The anthropometrical, physiological and skills test results are shown in table 6.

Table 6: Mean anthropometric, physiological and skill test of age group hockey players, based on pre season tests (boys).

U13	N	ATTACK MEAN	STDEV	N	DEFENCE MEAN	STDEV	P VALUE
ANTHROPOMETRIC							
Height (kg)	7	1.49	± 0.06	3	1.51	± 0.06	n/s
PHYSIOLOGICAL							
Situps	7	47.86	± 4.88	2	40.00	± 4.90	P<0.05
Pushups	7	59.71	± 8.77	3	61.67	± 8.77	n/s
Flex	7	40.29	± 4.79	3	36.67	± 4.79	n/s
B/Jump	7	178.00	± 13.40	3	173.33	± 13.40	n/s
Winder	4	3.81	± 0.46	1	4.16	± 0.46	

U14	N	ATTACK MEAN	STDEV	N	DEFENCE MEAN	STDEV	P VALUE
ANTHROPOMETRIC							
Height (m)	10	157.00	± 9.08	4	160.00	± 11.17	n/s
Weight (kg)	10	45.80	± 8.84	4	52.80	± 11.79	n/s
% BF	10	7.36	± 0.99	4	9.00	± 1.84	P<0.05
LBM (kg)	10	42.40	± 8.12	4	47.90	± 10.11	n/s
Body Fat (kg)	10	3.40	± 0.85	4	4.82	± 1.80	P<0.05
PHYSIOLOGICAL							
Situps	10	40.50	± 8.30	4	38.30	± 4.11	n/s
Pushups	10	32.20	± 9.64	4	36.00	± 28.57	n/s
Flex	7	46.40	± 6.08	3	50.00	± 1.73	n/s
B/Jump	10	190.10	± 17.08	4	187.80	± 24.65	n/s
Winder	13	3.66	± 0.33	5	3.89	± 0.40	n/s
Beep	15	10.30	± 1.72	5	10.00	± 1.11	n/s

U16	N	ATTACK MEAN	STDEV	N	DEFENCE MEAN	STDEV	P VALUE
ANTHROPOMETRIC							
Height (m)	12	168.00	± 6.97	6	166.70	± 9.52	n/s
Weight (kg)	12	58.00	± 7.32	6	56.50	± 12.42	n/s
% BF	12	8.65	± 1.68	6	8.10	± 0.72	n/s
LBM (kg)	12	52.89	± 6.34	6	51.87	± 11.28	n/s
Body Fat (kg)	12	5.06	± 1.34	6	4.59	± 1.19	n/s
PHYSIOLOGICAL							
Situps	12	42.00	± 11.00	6	36.33	± 11.78	n/s
Pushups	12	41.83	± 10.91	6	39.50	± 9.46	n/s
Flex	8	44.44	± 6.44	5	43.60	± 3.51	n/s
B/Jump	12	2.02	± 0.19	6	2.02	± 0.14	n/s
SKILLS							
Bounce R	14	51.79	± 28.44	6	61.50	± 21.53	n/s
Bounce L	14	18.50	± 8.12	6	18.17	± 8.38	n/s
Yard	14	102.70	± 22.28	6	97.83	± 30.22	n/s
Tuck	14	32.60	± 3.86	7	33.10	± 2.73	n/s
Rev Push T	14	25.14	± 3.37	6	23.67	± 2.07	n/s
Rev Push S	13	2.62	± 1.19	5	2.20	± 0.84	n/s
Front Push T	14	26.56	± 2.67	6	27.51	± 2.12	n/s
Front Push S	14	2.64	± 1.15	6	2.50	± 1.38	n/s
Hit Forw T	14	31.43	± 3.80	6	32.83	± 3.76	n/s
Hit Forw S	14	5.93	± 2.34	6	5.00	± 2.61	n/s

Table 6 continued: Mean anthropometric, physiological and skill test of age group hockey players, based on pre season tests (boys).

U18	N	ATTACK MEAN	STDEV	N	DEFENCE MEAN	STDEV	P VALUE
ANTHROPOMETRIC							
Height (m)	20	172.25	± 7.91	11	173.91	± 8.23	n/s
Weight (kg)	20	63.95	± 8.43	11	66.09	± 8.51	n/s
%BF	17	7.60	± 1.37	12	8.12	± 1.29	n/s
LBM (kg)	16	59.98	± 6.19	9	60.84	± 8.41	n/s
Body Fat (kg)	16	5.01	± 1.27	9	5.43	± 1.40	n/s
PHYSIOLOGICAL							
Situps	22	40.45	± 6.76	14	38.14	± 7.30	n/s
Pushups	23	41.78	± 8.69	12	40.83	± 6.98	n/s
Flex	22	44.95	± 6.95	14	47.00	± 6.82	n/s
B/Jump	20	228.30	± 16.32	14	216.79	± 23.52	P=0.05
Bleep	18	12.94	± 1.66	14	12.21	± 2.39	n/s
Level	18	5.11	± 4.09	14	4.36	± 5.69	n/s
SKILLS							
Bounce R	13	38.15	± 22.23	15	30.60	± 11.25	n/s
Bounce L	13	13.15	± 4.81	15	15.47	± 10.49	n/s
Yard	14	116.14	± 16.69	15	103.20	± 21.44	P<0.05
Tuck	16	31.13	± 4.36	15	31.87	± 3.50	n/s
Rev Push T	16	21.79	± 3.78	15	22.58	± 3.07	n/s
Rev Push S	16	2.94	± 1.34	15	2.00	± 1.13	P<0.05
Front Push T	16	24.73	± 3.39	15	22.85	± 4.37	n/s
Front Push S	16	2.56	± 1.21	15	2.73	± 1.22	n/s
Hit Forw T	16	28.59	± 5.02	15	27.96	± 4.63	n/s
Hit Forw S	16	4.44	± 2.31	15	4.07	± 1.49	n/s

U21	N	ATTACK MEAN	STDEV	N	DEFENCE MEAN	STDEV	P VALUE
ANTHROPOMETRIC							
Height (m)	10	179.85	± 8.31	2	176.00	± 4.24	n/s
Weight (kg)	10	65.35	± 11.08	2	61.75	± 15.20	n/s
PHYSIOLOGICAL							
Situps	10	41.00	± 9.02	2	34.00	± 5.66	n/s
Pushups	10	49.00	± 10.24	2	46.00	± 1.41	n/s
Flex	10	44.00	± 6.33	2	43.25	± 5.30	n/s
Flex	10	44.55	± 6.00	2	43.25	± 4.60	n/s
B/Jump	10	232.30	± 17.66	2	222.00	± 7.07	n/s
B/Jump	10	224.90	± 40.27	2	233.50	± 2.12	n/s
Bleep	14	12.71	± 1.64	9	13.44	± 1.33	n/s
Level	14	2.21	± 2.64	8	2.38	± 3.02	n/s

ANTHROPOMETRY

In terms of the anthropometric measures there were no statistical differences between positions in an age group except in the U14 where the attackers had a lower percentage body fat than defenders. In the literature reviewed it was found that in elite players the attacking players were shorter and lighter with a low percentage body fat than the defence who were heavier and taller (Malhorta *et al*, 1974). This may mean that the profiles of youth may not necessarily be similar to the elite players. Since the boys are still growing their body weights and heights are still changing and have not reached adult values (except for the U21) and should therefore not expect to be similar to elite players.

PHYSIOLOGICAL TESTS

The attackers were significantly better than the defenders at sit-ups in the U13 groups ($P<0.05$) and at broad jump in the U18 ($P<0.05$). All the other values were statistically not significantly different. It appears that in the U13 the attackers have stronger abdominal muscles. However, it is possible that the small sample size of 7 in the attackers and 2 in the defenders may have resulted in skewed data.

The better results for the attacking players in the broad jump test (U18) reflect stronger leg power which is an important part of the physiological profile of elite hockey players (Reilly and Borrie, 1992). Strong leg power is required to accelerate the body mass in hockey and particularly in the attackers because they are required to perform short runs with rapid acceleration. Reilly and Borrie (1992) also state that acceleration is more critical to hockey performance than maximal speed.

SKILL TESTS

In all the skills tests there were no differences in the U16 group, while the forwards in the U18 group were significantly better than the defenders in 2 of the 10 tests performed.

There are no known articles published regarding these skills or if there are any differences in skills between players of different field positions

GIRLS

The anthropometrical, physiological and skills test results are shown in table 7.

ANTHROPOMETRY

No significant differences are shown between the profiles of attack and defence players in the U13 group. The U14 reflect a difference with the defenders being taller, 1.48m and 1.54m, respectively, heavier and fatter with a percentage body fat of 14.2 and 16. 5 % respectively ($P <0.05$). This appears to be consistent with the elite players where the attacking players have a lower percentage body fat than the defending players and the defending players are taller than the attacking players (Kansal *et al*, 1980; Bale and Davis, 1983). The U16 showed no difference in the

Table 7: Mean anthropometric, physiological and skill test of age group hockey players, based on pre season tests (girls).

U13	N	ATTACK MEAN	STDEV	N	DEFENCE MEAN	STDEV	P VALUE
ANTHROPOMETRIC							
Height	2	1.48	± 0.04	7	1.54	± 0.08	n/s
PHYSIOLOGICAL							
Situps	2	33.50	± 9.19	7	35.25	± 4.06	n/s
Pushups	2	49.00	± 4.24	7	55.25	± 13.05	n/s
Flex	2	46.00	± 5.66	7	46.25	± 4.27	n/s
Flex	2	46.50	± 7.78	7	48.00	± 4.07	n/s
B/Jump	2	162.50	± 4.95	7	175.00	± 13.79	n/s
B/Jump	2	175.00	± 7.07	7	172.63	± 15.11	n/s

U14	N	ATTACK MEAN	STDEV	N	DEFENCE MEAN	STDEV	P VALUE
ANTHROPOMETRIC							
Height	17	1.56	± 0.05	9	1.61	± 0.05	P<0.05
Weight	17	49.21	± 5.67	9	55.00	± 5.67	P<0.05
% BF	17	14.20	± 4.55	9	16.54	± 4.55	n/s
LBM	17	42.02	± 3.99	9	45.83	± 3.99	P<0.05
BF	17	7.14	± 3.00	9	9.12	± 3.00	P<0.05
PHYSIOLOGICAL							
Situps	17	36.29	± 7.82	9	35.11	± 7.82	n/s
Pushups	15	44.47	± 9.80	9	48.67	± 9.80	n/s
Flex	17	46.30	± 7.02	8	45.23	± 7.02	n/s
Flex	17	47.83	± 6.23	8	45.51	± 6.23	n/s
B/Jump	17	175.35	± 21.79	9	176.22	± 21.79	n/s
Winder	12	4.08	± 0.28	4	4.12	± 0.28	n/s
Bleep	19	7.97	± 1.16	8	6.90	± 1.16	P<0.05

U16	N	ATTACK MEAN	STDEV	N	DEFENCE MEAN	STDEV	P VALUE
ANTHROPOMETRIC							
Height	35	162.83	± 5.28	13	163.08	± 5.35	n/s
Weight	35	53.36	± 7.03	13	55.15	± 6.90	n/s
% BF	35	16.27	± 3.02	11	16.88	± 3.18	n/s
LBM	35	42.55	± 9.40	10	45.36	± 5.24	n/s
BF	33	8.72	± 2.32	10	9.28	± 2.75	n/s
PHYSIOLOGICAL							
Pushups	35	34.11	± 8.85	13	31.69	± 10.55	n/s
B/Jump	35	1.75	± 0.13	13	1.68	± 0.15	n/s
SKILLS							
Bounce R	34	34.35	± 21.03	15	25.27	± 11.45	P=0.06
Bounce L	34	11.76	± 7.23	15	10.07	± 7.57	n/s
Yard	29	106.52	± 26.59	12	107.25	± 21.03	n/s
Tuck	34	27.71	± 5.51	16	27.13	± 5.97	n/s
Rev Push T	33	29.50	± 4.76	15	30.15	± 6.15	n/s
Rev Push S	32	2.25	± 1.16	15	1.87	± 1.30	n/s
Front Push T	34	28.88	± 5.59	15	28.73	± 4.23	n/s
Front Push S	34	2.03	± 1.42	15	2.13	± 1.36	n/s
Hit Forw T	34	34.51	± 4.91	15	34.81	± 5.36	n/s
Hit Forw S	34	4.29	± 1.99	15	3.40	± 2.29	n/s

profiles of attack and defence players. In the U18 and U21 the defenders were again shown to be heavier (P<0.05) and fatter (P<0.01). This is consistent with the findings in the literature where the defending players are taller and heavier than the attacking players (Malhorta *et al*, 1974; Bale and Davis, 1983; Bale 1981).

Table 7 continued: Mean anthropometric, physiological and skill test of age group hockey players, based on pre season tests (girls).

U18	N	ATTACK MEAN	STDEV	N	DEFENCE MEAN	STDEV	P VALUE
ANTHROPOMETRIC							
Height	26	162.62	6.47	13	164.08	5.66	n/s
Weight	26	53.44	7.61	13	60.12	5.87	P<0.01
%BF	27	15.92	3.02	13	18.07	3.85	P<0.05
LBM	26	43.39	9.40	12	48.81	4.40	P<0.05
BF	25	8.53	2.67	11	11.05	3.06	P<0.05
PHYSIOLOGICAL							
Situps	25	36.80	7.04	12	37.17	10.49	n/s
Pushups	25	40.92	9.93	13	37.31	8.43	n/s
Bjump	27	177.72	10.78	12	173.42	12.28	n/s
B/Jump	27	178.17	10.85	12	176.46	10.52	n/s
Winder	12	4.12	0.24	13	4.08	0.27	n/s
SKILLS							
Bounce R	15	10.40	3.56	11	11.82	4.50	n/s
Bounce L	15	5.47	1.92	11	6.82	3.01	n/s
Yard	16	111.81	30.17	10	114.70	17.66	n/s
Tuck	23	27.26	4.87	12	28.83	3.57	n/s
Rev Push T	23	26.98	4.60	12	25.91	2.46	n/s
Rev Push S	23	1.87	1.10	12	1.75	0.70	n/s
Front Push T	23	27.88	3.44	12	27.82	4.89	n/s
Front Push S	23	2.09	1.20	12	1.67	1.27	n/s
Hit Forw T	22	33.11	3.84	12	33.85	3.89	n/s
Hit Forw S	22	4.18	1.84	12	4.92	2.21	n/s

U21	*N*	ATTACK MEAN	STDEV	N 9	DEFENCE MEAN	STDEV	P VALUE
ANTHROPOMETRIC							
Height	13	163.92	± 6.76	9	163.67	± 7.28	n/s
Weight	13	56.00	± 7.22	8	66.00	± 6.32	P<0.01
%BF	11	15.88	± 1.78	7	19.35	± 3.02	P<0.01
LBM	11	48.20	± 5.25	7	52.45	± 4.28	P<0.05
Body Fat	11	9.19	± 1.84	10	12.80	± 3.13	P<0.01
PHYSIOLOGICAL							
Situps	13	43.08	± 10.94	10	46.80	± 18.82	n/s
Pushups	13	36.46	± 9.73	10	33.80	± 15.60	n/s
Bjump	13	190.38	± 13.42	10	177.70	± 21.72	P<0.05
B/Jump	13	189.38	± 17.60	8	176.70	± 26.04	n/s
Winder	11	4.03	± 0.32	7	4.09	± 0.25	n/s
SKILLS							
BoL	8	9.13	± 4.73	8	6.50	± 2.33	n/s
BOR	8	16.50	± 6.85	8	15.50	± 5.71	n/s
Yard	8	147.63	± 26.07	8	129.88	± 22.26	n/s
Tuck	9	34.22	± 4.76	8	35.50	± 9.77	n/s
Front Push t	9	27.67	± 6.65	8	24.43	± 4.89	n/s
Front Push s	9	2.89	± 1.27	8	3.50	± 1.41	n/s
Reverse Push	9	26.27	± 5.37	8	29.13	± 7.79	n/s
Reverse Push	9	3.33	± 1.22	8	2.38	± 1.30	P=0.06
Hit For t	9	31.18	± 5.56	8	30.65	± 5.64	n/s
Hit For s	9	4.22	± 1.39	7	4.25	± 2.49	n/s

PHYSIOLOGICAL TESTS

Very few differences were noted in the physiological tests. The attackers were better at the bleep test, U14, and broad jump, U21 (P<0.05, and P<0.05 respectively). The literature indicates that there is no difference in aerobic power amongst field players while anaerobic power is better in the attacking players than defence players (Ghosh *et al*, 1988). However, the results of the winder test in the U14 was statistically not significant and as it also tests for aerobic capacity. It cannot definitely be concluded that the aerobic capacity of the attacking players in the U14 is better than the defence players.

The sit-up and push up tests, test muscular endurance and the broad jump tests power, which are both essential for all players and should not differ in terms of field positions. Thus, the lack of any distinct variation in physiological characteristics measured in this study tends to confirm the finding in the literature that only physical characteristics vary with field positions.

SKILL TESTS

In the skills tests in all the age groups the results reflect no significant difference in the skills of the attacking and defending players. This could mean that the skills of attacking and defending players are identical or that the tests are not discriminative enough to determine differences in ball skills between players in different field positions. It is expected that there ought to be a difference in the ball skills as attacking players should have greater dribbling skills and defending players more defensive skills. The designing of skills tests to determine differences in skills of attacking and defending players needs to be studied in more detail. From such a study new tests will be designed to determine the difference in the different ball skills of attacking and defending players.

3.3 PRE AND END SEASON COMPARISON

BOYS

Only the U13, U14 and U16 were tested and the results are presented in Table 8.

ANTHROPOMETRY

The numbers tested in the U13 were very small between 2 and 4 and may not be a representative sample. They will not be discussed further, except to note the apparently significant decline in push-ups ($P<0.005$).

In all the groups the change in the mean height was significant, reflecting that the boys had grown taller, which is expected ($P<0.001$).

In the U14 group there was a significant increase in push-ups ($P<0.001$) but a decrease in the broad jump ($P<0.001$). This is noteworthy as the group had grown during this time, and broad jump was shown to correlate with height.

In the U16 all the results were statistically significant with improvements in all the variables except in the sit-ups where the increase did not reach statistical significance. This improvement could be attributed to the training programme during the season. There was an improvement in the mean flexibility values, which could also be due to training.

The improvement in the strength and muscular endurance in the above groups could either be attributed to the training programmes or to the improvement in strength with growth. The issue of trainability remains controversial according to the literature. Strength naturally increases with growth, probably reaching a peak during the adolescent growth spurt in girls, and a year after in boys (Potthast and Klimt, 1988). Nielsen *et al* (1980) suggested that suitable resistance training in girls results in strength gains throughout their phases of development, before, during or after puberty. Similarly, boys can also train to improve their strength. There is uncertainty whether strength trainability remains the same throughout the growth phases and whether the pre-pubescent might have greater trainability in strength than older age groups (Nielsen *et al*, 1980) or vice versa (Vrijens, 1988).

Table 8: Mean Anthropometric, Physiological, and Skill test of age group hockey players, based on pre and end season (boys).

U13		APR		OCT		
	N	MEAN	STDEV	MEAN	STDEV	P VALUE
ANTHROPOMETRIC						
Height	4	1.44	±0.10	150.50	±8.82	P<0.001
PHYSIOLOGICAL						
Situps	3	44.67	±5.03	45.67	±5.51	n/s
Pushups	3	59.67	±12.50	39.00	±12.12	P<0.005
Flex	4	40.75	±4.35	41.00	±4.14	n/s
B/Jump	3	1.79	±0.07	2.03	±0.06	P<0.05
Winder	2	3.83	±0.47	3.84	±0.35	n/s

UI4		APR		OCT		
	N	MEAN	STDEV	MEAN	STDEV	P VALUE
ANTHROPOMETRIC						
Height	13	1.58	±0.09	1.67	±0.10	P<0.001
PHYSIOLOGICAL						
Situps	13	39.54	±7.64	43.69	±8.36	P=0.06
Pushups	13	26.08	±8.97	41.23	±11.02	P<0.001
Flex	13	40.77	±4.69	41.00	±7.52	n/s
B/Jump	11	2.01	±0.12	1.87	±0.18	P<0.005
Winder	17	3.72	±0.38	3.78	±0.39	n/s

U16		APR		*OCT*		
	N	MEAN	STDEV	MEAN	STDEV	P VALUE
ANTHROPOMETRIC						
Height	13	1.71	±0.08	1.73	±0.06	P<0.001
PHYSIOLOGICAL						
Situps	17	40.41	±9.36	47.94	±8.40	P<0.001
Pushups	17	39.41	±8.48	42.24	±7.08	n/s
Flex	10	42.25	±5.54	44.40	±4.09	P<0.05
B/Jump	14	2.03	±0.18	2.25	±0.10	P<0.001
SKILLS						
Bounce R	15	52.13	±22.00	29.93	±14.04	P<0.005
Bounce L	15	17.07	±7.16	10.47	±6.17	P<0.05
Yard	19	102.00	±24.33	114.42	±16.30	P<0.05
Tuck	15	32.67	±4.03	37.60	±3.94	P=0.001
Rev Push T	12	23.33	±2.71	22.64	±1.60	n/s
Rev Push S	12	2.45	±1.21	2.27	±0.90	n/s
Front Push T	12	27.47	±1.44	26.03	±3.39	n/s
Front Push S	12	2.67	±1.23	3.00	±1.41	n/s
Hit Forw T	16	32.38	±3.59	34.75	±1.94	P<0.05
Hit Forw S	16	5.69	±2.21	6.44	±1.86	P<0.05

In the skills test for the U16, four of the tests were significantly improved, while two were significantly worse. It is expected that there should have been a general improvement in all the skills by the end of the season. Since there is no consistent pattern of improvement in all the skills it suggests that the skill training programme was inadequate. The worth of the ball bouncing skill should be questioned.

GIRLS

In Table 9 the results of the paired t-test for girls are presented for all the groups except the U21 who were not tested. Not all the tests were performed and the U16 had the largest sample size and most of the variables tested.

All the age groups showed significant increase in height during the season, which is expected ($P<0.001$).

The results for sit-ups, push-ups, flexibility and broad jump in the U13 show no significant differences between the pre season and end season results. This suggests that the training programme had minimal effect on the physiological performance during the season, perhaps due to inadequate training or poor technique. The sample was however, small.

In all the other age groups (U14, U16 and U18) the results for the sit-ups and broad jump significantly improved during the season. The results for the push-up test was variable with an improvement noted in the U16 and U18 groups.

This variation in results in the physiological tests reflects the possibility that the training programme was not adequate or that the training programme varied in the different groups. The literature reflects that there should be an improvement in physiological characteristics with age and or training.

The improvement in some of the physiological variables in the groups may be attributed to the training programmes or improvement with growth. Since there were no control groups in this study it would be difficult to conclude which factors

Table 9: Mean anthropometric, physiological and skill test of age group hockey players, based on pre and end season results (girls).

U13		APR		OCT		
	N	MEAN	STDEV	MEAN	STDEV	P VALUE
ANTHROPOMETRIC						
Height	7	1.52	± 0.08	1.55	± 0.08	P<0.001
PHYSIOLOGICAL						
Situps	7	33.29	± 4.82	27.29	± 9.60	n/s
Pushups	7	52.57	± 13.99	43.71	± 13.38	n/s
Flex	6	46.00	± 3.56	47.25	± 3.49	n/s
B/Jump	5	1.64	± 0.12	1.60	± 0.18	n/s

Ul4		APR		OCT		
	N	MEAN	STDEV	MEAN	STDEV	P VALUE
ANTHROPOMETRIC						
Height	9	1.56	± 0.07	1.61	± 0.07	P<0.001
PHYSIOLOGICAL						
Situps	14	37.86	± 6.81	53.64	± 8.27	P<0.001
Pushups	14	48.79	± 12.91	41.21	± 9.88	n/s
Flex	9	48.78	± 3.76	46.75	± 4.76	P=0.05
B/Jump	12	1.78	± 0.15	1.98	± 0.31	P=0.06

U16		APR		OCT		
	N	MEAN	STDEV	MEAN	STDEV	P VALUE
ANTHROPOMETRIC						
Height	20	163.20	± 5.50	1.64	± 5.35	P<0.001
PHYSIOLOGICAL						
Situps	28	35.21	± 5.01	40.76	± 4.74	P<0.001
Pushups	25	35.20	± 7.62	43.36	± 10.40	P<0.001
B/Jump	21	1.77	± 0.14	1.89	± 0.11	P<0.001
Winder	7	4.16	± 0.04	4.23	± 0.14	P=0.06
SKILLS						
Bounce R	22	34.59	± 23.79	23.23	± 13.92	P<0.05
Bounce L	22	12.95	± 8.33	8.45	± 6.17	P<0.005
Yard	21	110.62	± 18.10	114.29	± 16.81	n/s
Tuck	17	29.24	± 5.08	39.18	± 4.05	P<0.001
Rev Push T	20	28.65	± 3.12	25.62	± 1.61	P<0.001
Rev Push S	19	2.47	± 0.90	2.79	± 1.44	n/s
Front Push T	20	27.00	± 3.87	27.13	± 2.95	n/s
Front Push S	19	2.26	± 1.56	2.39	± 1.14	n/s
Hit Forw T	19	32.82	± 3.16	29.70	± 2.96	P<0.01
Hit Forw S	19	4.37	± 2.31	4.84	± 1.46	P<0.5

U18		APR		OCT		
	N	MEAN	STDEV	MEAN	STDEV	P VALUE
ANTHROPOMETRIC						
Height	5	163.80	± 5.59	1.63	± 0.06	P<0.001
PHYSIOLOGICAL						
Situps	11	35.18	± 6.87	50.00	± 11.46	P<0.001
Pushups	13	40.54	± 11.59	43.92	± 11.51	n/s
B/Jump	7	1.82	± 0.09	1.89	± 0.16	P<0.05
SKILLS						
Bounce R	4	9.00	± 1.41	10.25	± 2.06	n/s
Bounce L	5	4.80	± 1.30	3.40	± 0.89	P<0.01
Yard	17	118.88	± 20.94	117.69	± 19.35	n/s
Tuck	9	27.78	± 3.60	12.33	± 2.12	P<0.001

contributed to the improvement. However, if growth was a major factor then there should be an improvement in all the physiological tests except perhaps flexibility which tends to decrease with age but could improve with training. This is further complicated by the fact that some of the subjects within the age groups may have been going through a growth spurt phase which may affect strength.

The results of the winder test in the U13 and U14 showed no significant difference. The values were almost identical in the pre and end season results. This suggests that the aerobic capacity did not change during the season either with training or growth, this test is however motivation dependent.

In the skills test only the U16 were tested for all and in the U18 only four skills were tested. The results in both groups reflect a great variation with some improvement of skills and a deterioration of others. There was no clear pattern of improvement in the ball skills which might be expected at the end of season as a result of the training. This may reflect that the tests are not appropriate or reliable indicators of match skills.

4. SUMMARY

The anthropometric data for boys showed the expected increases in height and weight with age. The percentage body fat was lower than the norm given for age 17 years. The girls showed similar changes.

The physiological values reflect an improvement in the flexibility and broad jump across the age groups, however, the U13 groups performed better in the push-ups. The physiological values for the girls show a significant improvement in number of sit-ups but a decline in the number of push-up.

The aerobic test reflected no change across the age groups. The skills tests revealed no distinct pattern of improvement or change across the age groups in both boys and girls. No particular age group excelled in these skills and it seems that there is no difference in the ball skills in these groups which is contrary to what is expected that the older groups perform better because of their experience and training. The validity of these tests should be questioned.

In the boys, comparison of attackers and defenders showed that there appeared to be no significant difference between positions in the anthropometric measures, physiological characteristics and skills tests. The literature reflects difference in the elite players, but the current study indicates the profiles of youth may not necessarily be similar to the elite players. In the girls the results were consistent with the literature in that the defence players were heavier and taller than the attacking players (this was especially in the U14 and U18). In the U21 the heights were identical but the defenders were heavier than the attack players. The other age groups showed no significant changes. In the physiological and skill test there were no consistent differences between the attack and defence players.

In the pre and end season comparison in the boys and girls the only anthropometric measure was height and that naturally reflected an improvement during the season. All the physiological and skills tests in both sexes showed a variation in the results. There appeared to be no distinct pattern of improvement in any particular physiological variable.

A number of limitations were experienced in the current study. Not all the anthropometric measures were made at the end of season and therefore the comparison was not adequate. A number of tests were not done for example, the sprint tests (to test anaerobic power) or the 3km run to test aerobic power and the winder and bleep was not tested amongst all the age groups.

Any future study should address the above limitations and also include tests that have been omitted in this study. The normative data established in this study will be the first set of normative data to be used in the FITTEST computer programme designed by Angus *et al* (1993).

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6. APPENDIX

6.1 TABLES FOR END SEASON RESULTS

TABLE 1: RESULTS FOR END SEASON BOYS (ANOVA)

	U13			U14			U16			
	N	MEAN	STDEV	N	MEAN	STDEV	N	MEAN	STDEV	P VALUE
ANTHROPOMETRIC										
Height	16	1.51	±0.09	28	1.65	±0.09	19	1.73	±0.06	P<0.001
PHYSIOLOGICAL										
Situps	14	43.36	±7.31	26	42.58	±7.12	24	47.96	±9.20	P=0.05
Pushups	14	41.21	±10.84	26	39.15	±9.47	24	42.63	±7.65	n/s
Flex	16	43.50	±4.39	28	41.25	±6.05	19	44.89	±4.63	P0.06
B/Jump	17	2.06	±0.20	24	2.03	±0.14	20	2.27	±0.12	P<0.001
Winder	16	4.12	±0.28	27	3.79	±0.35	19	3.36	±0.10	P<0.001
SKILLS										
Bounce R	18	27.44	±14.13	22	12.68	±8.85	20	29.25	±12.80	P<0.001
Bounce L	18	13.06	±6.76	22	6.18	±4.07	20	12.50	±7.18	P<0.001
Yard				22	99.95	±9.63	24	110.38	±16.70	P<0.01
Tuck	18	35.39	±3.29	22	40.14	±4.14	20	37.60	±3.93	P<0.001
Rev Push T	10	24.30	±2.41	27	26.30	±2.55	14	22.84	±1.74	P<0.001
Rev Push S	10	2.90	±1.20	27	3.26	±1.38	14	2.36	±0.84	n/s
Front Push T	10	22.70	±2.21	27	27.89	±4.00	14	25.96	±3.28	P<0.001
Front Push S	10	1.60	±1.07	27	2.04	±1.06	14	3.21	±1.53	P<0.005
Hit Forw T				14	35.54	±2.07	22	34.56	±2.05	P<0.5
Hit Forw S				14	5.36	±1.34	22	6.05	±1.91	n/s

TABLE 2: RESULTS FOR END SEASON GIRLS (ANOVA)

	U13			U14			U16			U18			
		MEAN	STDEV		MEAN	STDEV		MEAN	STDEV		MEAN	STDEV	PVALUE
ANTHROPOMETRIC													
Height	10	1.55	± 0.06	17	1.62	± 0.07	22	1.64	± 0.05	6	1.64	± 0.06	P<0.01
PHYSIOLOGICAL													
Situps	14	30.57	± 7.83	23	51.26	± 9.42	27	40.26	± 5.29	14	49.14	± 11.72	P<0.001
Pushups	14	47.14	± 11.05	22	40.32	± 9.92	27	42.81	± 10.87	17	41.76	± 11.77	P<0.5
Flex	13	48.00	± 4.35	17	45.74	± 6.31	22	48.14	± 6.78	5	44.40	± 8.79	P<0.5
B/Jump	12	1.74	± 0.19	27	2.05	± 0.24	24	1.88	± 0.16	9	1.84	± 0.18	P<0.001
SKILLS													
Bounce R				26	22.96	± 10.56	26	24.12	± 13.12	8	9.75	± 4.27	P<0.01
Bounce L				27	7.37	± 3.01	26	8.00	± 5.79	9	3.67	± 1.32	P<0.05
Yard	13	85.92	± 16.16	20	109.30	± 14.90	26	111.23	± 17.66	28	114.04	± 20.20	P<0.001
Tuck	13	30.62	± 3.50	27	32.30	± 5.39	19	38.84	± 4.07	14	12.86	± 1.92	P<0.001
Rev Push T	8	27.29	± 2.22	13	24.70	± 2.86	21	25.66	± 1.64				P<0.05
Rev Push S	8	2.13	± 1.13	13	1.38	± 0.96	21	2.76	± 1.37				P<0.001
Front Push T	8	32.18	± 3.85	13	31.92	± 4.96	21	27.01	± 2.90				P<0.001
Front Push S	8	2.38	± 1.77	13	2.23	± 1.01	20	2.40	± 1.19				n/s
Hit Forw T				10	32.50	± 4.96	20	29.57	± 2.94				P=0.05
Hit Forw S				10	5.20	± 5.00	20	0.63	± 1.59				n/s

6.2 TABLE OF LEVEL VALUES FOR BLEEP TEST

NAME	No	FEATURES	LAP	Name/No	VO2	LAP	Name/No	VO2	Lap	Name/No	VO2	Lap	Name/No	VO2	Lap	Name/No	VO2
	1		45		34.3	82		46.4	13-119		57.3	157		67.5	194		76.4
	2		46		34.6	83		46.8	120		57.6				195		76.7
	3		47		35				121		57.9	16-158		67.7	196		76.9
	4		48		35.3	10-84		47.1	122		58.2	159		68	197		77.2
	5		49		35.7	85		47.4	123		58.4	160		68.2	198		77.4
	6		50		36	86		47.7	124		58.7	161		68.5	199		77.6
	7		51		36.4	87		48	125		59	162		68.7	200		77.9
	8					88		48.3	126		59.3	163		69			
	9		7-52		36.7	89		48.7	127		59.5	164		69.2	19-201		78.1
	10		53		37.1	90		49	128		59.8	165		69.5	202		78.3
DATE:			54		37.4	91		49.3	129		60.2	166		69.7	203		78.5
VENUE:			55		37.8	92		49.6	130		60.4	167		69.9	204		78.6
CLUB:			56		38.1	93		49.9	131		60.6	168		70.2	205		79
Completed Lap	Name	Pred. VO2	57		38.5	94		50.2				169		70.5	206		79.2
Level 1			58		38.8				14-132		60.8	170		70.7	207		79.4
Level 2			59		39.2	11-95		50.5	133		61.1	171		70.9	208		79.7
Level 3			60		39.5	96		50.8	134		61.4				209		79.9
4-24		26.4	61		39.9	97		51.1	135		61.7	17-172		71.1	210		80.2
25		26.8				98		51.4	136		61.9	173		71.4	211		80.4
26		27.2	8-62		40.2	99		51.6	137		62.2	174		71.6	212		80.6
27		27.6	63		40.5	100		51.9	138		62.4	175		71.9	213		80.8
28		28	64		40.8	101		52.2	139		62.7	176		72.1	214		81
29		28.3	65		41.1	102		52.5	140		62.9	177		72.4	215		81.3
30		28.7	66		41.4	103		52.8	141		63.2	178		72.6			
31		29.1	67		41.8	104		53.1	142		63.4	179		72.9	20-216		81.5
32		29.5	68		42.1	105		53.4	143		63.7	180		73.1	217		81.8
			69		42.4	106		53.7	144		64	181		73.4	218		82
5-33		29.8	70		42.7							182		73.6	219		82.2
34		30.2	71		43	12-107		54	15-145		64.3	183		73.9	220		82.4
35		30.6	72		43.3	108		54.3	146		64.6	184		74.1	221		82.6
36		31				109		54.5	147		64.8	185		74.4	222		82.8
37		31.4	9-73		43.6	110		54.8	148		65.1				223		83
38		31.8	74		43.9	111		55.1	149		65.3	18-186		74.6	224		83.2
39		32.2	75		44.2	112		55.4	150		65.6	187		74.8	225		83.5
40		32.6	76		44.5	113		55.7	151		66.9	188		75	226		83.7
41		32.9	77		44.8	114		56	152		66.2	189		75.3	227		83.9
			78		45.2	115		56.2	153		66.4	190		75.5	228		84.2
6-42		33.2	79		45.5	116		56.5	154		66.7	191		75.8	229		84.5
43		33.6	80		45.8	117		56.8	155		66.9	192		76	230		84.8
44		33.9	81		46.1	118		57.1	156		67.2	193		76.2			

6.3 CONSENT FORM FOR SUBJECTS

:4. INDEMNITY, DECLARATION AND SIGNATURE

The individual and/or his executors hereby indemnifies the KwaZulu Natal Hockey Association and the KwaZulu Natal Hockey Academy from any liability which may arise from any injury, illness, death, loss or damage from any cause arising which the individual (listed below) may sustain while attending the KwaZulu Natal Hockey Academy and partaking of its services.

I wish to be considered for entry to the KwaZulu Natal Hockey Academy, and I declare that all the information submitted on this application form is correct and complete. I understand that the Hockey Academy reserves the right to vary or reverse any decision regarding admission made on the basis of incorrect or incomplete information.

Signed at .... on the..day of...19....................
(day) (month) (year)

....
Signed by the KZNH Academy

....
Signed by Applicant

....
Assisted by Guardian/Parent