POSITIONAL ASSESSMENT OF SELECTED SKILL RELATED PHYSICAL FITNESS COMPONENTS AMONGST MALE KENYAN BASKETBALL PLAYERS

KAMANDE MWANGI ISAAC (B.Ed)

I56/5662/03

A Thesis submitted in partial fulfillment of the requirements for the award of the degree of Master of Science in the School of Health Sciences of Kenyatta University

October 2007

Declaration

This is my original work and has not been presented in any other university for a university degree or any other award.

Signature ______________________ Date 4/10/2007

Kamande Mwangi Isaac
Reg. Number I56/5662/03

This work has been submitted with the approval of my supervisors.

Supervisors

Signature ______________________ Date 10/10/2007

Njororai W. W. Simiyu, Ph. D.
Senior Lecturer
Department of Exercise, Recreation and Sport Science

Signature ______________________ Date 10th Oct. 2007

M. P. Wanderi, Ph. D
Senior Lecturer
Department of Exercise, Recreation and Sport Science

Dedication

To my family for the love, continued support and encouragement during the entire time of my studies – you are a gift to me from GOD.

Acknowledgement

The completion of this project would not have been possible without the contributions of a number of people.

First, to the almighty GOD for the good health, provision of resources and source of inspiration that fueled me to the completion of this project.

My special gratitude goes to my supervisors Dr. Njororai Simiyu and Dr. Wanderi Mwangi who not only offered academic guidance but also offered moral support. Their continued guidance in this project and in my academic life as a whole leaves me indebted.

Gratitudes also go to my family for the patience, love and general support that they have shown me throughout my studies. Their selflessness cannot go unmentioned. God bless them for all their sacrifice and belief in me.

My sincere gratitude goes to my employer Strathmore University for allowing me time off to do my studies. The resources offered by the university have been of great help throughout my studies.

Finally to all my colleagues and classmates in sports, who I have always consulted in the profession, I thank them for their help and support in various ways.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

KBF – Kenya Basketball Federation

ATP – Adenosine Triphosphate

PCr – Phospho - Creatine System

SEMO Agility Test - South East Missouri Agility Test

La – O_2 – Lactic acid System

VO_2 Max – Maximum amount of energy in millimeters a player can consume while exercising at maximum capacity

NCAA – National Collegiate Athletics Association

ABSTRACT

The game of basketball requires a mastery of several skills to play and perform well in a competition. The aim of this study was to establish the differences in the selected skill related components of physical fitness in relation to playing positions amongst male basketball players during the Kenya Basketball Federation (KBF) 2005 Premier League season. The study assessed agility, leg explosive power and aerobic capacity in relation to playing positions. The league comprised 10 teams of 12 registered players each, thus the target population was 120 players. The sample included 48 male basketball players from 4 teams which is 40% of the total population. A stratified random sampling procedure was used to select the teams used in the study. Strathmore University "Blades" male basketball players were used for the pilot study. An ex-post facto research design was used in this study. The data obtained through this study was subjected to statistical analysis using Statistical Package of Social Sciences (S. P. S. S.). Descriptive statistics of mean and standard deviation were used in the analysis of the data. One-way analysis of variance (ANOVA) was used to test the research hypotheses. The data collected were then presented using tables. Four hypotheses were tested and the results showed that there were no significant differences in agility amongst the guards who were 23 (48% of the total population), forwards 17 (35%) and centers 8 (17%) at $p < 0.05$. There were no significant differences in leg explosive power amongst the guards, forwards and centers at $p < 0.05$. There were also no significant difference in aerobic capacity amongst guards, forwards and centers at $p < 0.05$. The null hypotheses proposed were therefore not rejected. The players did not show significant differences in the scores of the components tested and this was attributed to the lack of specificity during training which takes place in total contrary to the specific requirements of the positional roles. The study recommended further research to establish the training regimens followed by various teams during the off-season and in the competitive season and especially as regards the requirements of the positional roles not only in basketball but also in other sports. The study also recommended that Kenya Basketball Federation and the clubs initiate fitness testing programmes so as to establish norms for the Kenyan basketball players. This would help to form a basis for developing the selection criteria and guidelines for policy formulation.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Problem

The various components of play in basketball have their own physical requirements, such as the ability to jump high, flexibility, agility and speed for movement around the court. Furthermore, since basketball matches last 48 minutes or more, muscular and cardio respiratory endurance are also needed where many basketball players today at high school, college and professional levels train to enhance their jumping ability, speed, aerobic endurance and anaerobic power (Wootten, 1992). However, data describing the physical prowess of the modern basketball players are sparse (Latin *et al.*, 1994). The game of basketball lacks material support of the use of specific training to enhance performance especially at school level. This clearly justifies the need to assess the physical fitness profiles of the basketball players.

Latin *et al.* (1994) cite several investigations that have monitored conditioning over a season or described specific characteristics of basketball players such as muscle force production characteristics, pulmonary function and maximal oxygen consumption (VO_2 max). However, there have been few attempts to profile a large sample of basketball players. Sample sizes have been small ranging from 14 – 34. Of the literature reviewed, very few have attempted to relate the investigated profiles to the specific requirements of playing positions in the highly technical game of basketball. Literature on Kenyan basketball players was lacking.

Every sport has specific requirements. As an illustration of this, Hoffman *et al.* (1992) demonstrated the importance of leg strength, vertical jump, height, speed and agility in determining the playing time of division one basketball players. The study above also indicated the importance of aerobic capacity and upper body strength in basketball performance. In the findings, it stated that in order to be competitive, basketball players need a high aerobic base. The information mentioned in the study above is very vital to the coaching staff and there is need therefore to localize such information through studies that use local players.

The game of basketball involves several basic playing skills such as running, jumping, catching, passing, rebounding, shooting, dunking and various combinations of movements. These attributes of the game call for variations in size, fitness level, specific technique, and offensive strategies. Therefore, players usually are assigned to different playing roles and positions. Generally, the roles of the players can be divided into the following five different positions: power forward, small forward, center, point guard, and shooting guard (Wu, 1998). Based on players' specific roles on the court, each position usually would demonstrate a unique style of play at different spots of the court. For example, forward players can be extremely active around the free-throw line extended area. They should be able to score both inside the marked area and the perimeter. The forwards are usually the best scorers of the team, and should be involved in some rebounding and passing duties as well. This is why most of the forwards need to possess great size, speed and leaping ability (Wu, 1998). Most of the centers work in an area less than 5m away from the basket (Wissel, 1994). They work at an area that is always under heavy traffic. Since the centers usually initiate the attack at the low-post area, they must possess skills to catch the ball firmly, seal off the defender, and use all kinds of fake moves to score (Wissel, 1994; Wu 1998). Centers must have ability to score one-on-one and secure rebounds. Defensively, they usually provide the best help on penetrations (Wootten, 1992); therefore, the strength of the center may indicate the success of the team. Guards are usually the "core" of a basketball team. They are usually the leaders and the organizers of the team offense. They normally operate at the top of the key and try to create shooting opportunities for other team mates by making good passes and penetration. They should be good long and mid-range shooters, and also score in penetrations (Wissel, 1994). Such differences as regards the playing positions and requirements can only be clearly brought out through the testing of various components in relation to playing positions.

In order to fully maximize the playing ability of each specific position, coaches would also teach necessary techniques to elevate player's individual skills. Possessing strong individual offensive skills is an essential element to build the team offenses and success. The skills that players have acquired would naturally become preferential moves under such circumstances in the game situation (Wissel, 1994). For coaches to understand their players well and impart the correct training through selected drills then an individual's well-known entry behavior is vital. Physical fitness testing will give such details as regards every player. According to Wu (1998), physical fitness of athletes directly determines successful application of the techniques, tactics and physiological abilities. Jeremy *et al.* (2004) note that, collegiate basketball players require a high level of aerobic fitness and optimal body composition profiles in order to maximize performance.

Unfortunately there is limited or no scientific information available concerning the physiological characteristics of basketball players in Kenya. This study is a first step towards the establishment of the physical fitness norms for Kenyan basketball players that may be used as a policy guideline for the Kenya Basketball Federation and the clubs as well. It is notable that a study relating to Kenyan basketball players has so far not been done in Kenya. This study therefore helped to bridge that gap by providing the physiological and physical attributes of the Kenyan male basketball players.

1.2 Statement of the Problem

Hoffman *et al.* (1996) assert that participation in an off-season strength and conditioning programme has been shown to improve strength, speed and explosive leg strength through vertical jump heights in college basketball players. They also add that typical training programmes usually incorporate strength, power, speed, agility, and endurance exercises directed towards improving the athletes' functional capacity. However, these components need to be evaluated during a basketball season and especially in relation to playing positions. In the absence of clear testing of the selected components, then there would be no understanding of the requirements of the players as per the positions played. Clear testing of various components of physical fitness would improve the game of basketball through specific training as per the positions played. The teams participating in the Kenya Basketball League did not have any recorded profiles on the players; nor did they have clear training programs with fitness testing appraisals. Such profiles are important as they would not only help the coaching staff but also the selectors to the national team, and hence this study. The focus of this study was therefore, on the three selected skill related components of physical fitness namely, aerobic capacity, agility and leg explosive power and also to relate the scores obtained to the positions of the male Kenyan basketball players.

1.3 Purpose of the Study

The purpose of the study was to assess the agility, explosive power, and aerobic capacity of the male basketball players who participated in the Kenya Basketball Federation 2005 Premier League, in relation to their playing positions.

1.4 Objectives of the Study

The objectives of this study were:

a) To generate the selected fitness and skill related profiles for male national league basketball players engaged in the KBF 2005 Premier League based on the aerobic capacity, agility and leg explosive strength.

b) To assess the effects of the changes on the agility, leg explosive strength and aerobic endurance.

c) To assess the differences in agility, leg explosive power and aerobic capacity in relation to players' positions.

d) To assess the interrelationships amongst agility, leg explosive power and aerobic capacity and the teams' performances in the KBF 2005 Premier League competition.

1.5 Research Hypotheses

The general hypothesis for the study was:

There would be no significant differences in agility, explosive power, and aerobic capacity of the Kenya Basketball Federation Premier League male basketball players in the 2005 season due to the positions played.

The specific null hypotheses were as follows:

HO1 There was no significant difference in agility among the guards, the forwards and the centers in the 2005 Kenya Basketball Federation Premier League.

HO2 There was no significant difference in leg explosive power among guards, forwards and centers in the 2005 Kenya Basketball Federation League.

HO3 There was no significant difference in aerobic capacity amongst guards, forwards and centers in the 2005 Kenya Basketball Federation League.

HO4 There was no significant difference in the age amongst male basketball players in the 2005 KBF premier league.

HO5 There was no significant difference in the playing experience amongst male basketball players in the 2005 KBF premier league

HO6 There was no significant difference in the height amongst male basketball players in the 2005 KBF premier league.

1.6 Conceptual Framework

Sports may be classified according to the temporal nature of the matches. In this regard, basketball is a game of four quarters and so falls into the category of those sports that have set time limits (Reilly *et al.*, 1990). It is also a game of high intensity exercise interspersed with rest periods. Therefore, technical demands of the game and the tactical systems employed have led to players adopting specific roles during matches. This imposes particular requirements on these players. For instance, there are variations in size, fitness level, specific technique, and offensive strategies, which in turn lead to players being assigned to different playing roles and positions. The requirements in the different playing positions can be assessed through physical fitness testing. Accordingly, Latin *et al.* (1994) has cited several investigations that have monitored conditioning over a season or described specific characteristics of basketball players such as muscle force production characteristics, pulmonary function and maximal oxygen consumption (VO_2 Max). Wu (1998) argues that, physical fitness of athletes directly determines successful application of techniques, tactics and physiological abilities.

The basis of this study was fitness testing and the goal of a testing programme is to optimize the evaluation of an athlete by using relevant tests that are specific to the sport. Besides the tests being specific to the sport, testing must bring out the specific aspects of the game and hence the needs and requirements of the game (Hoffman *et al.*, 1992). The tests presented here examined some major traits in the game of basketball. The multistage shuttle run, the South East Missouri (SEMO) agility test and the vertical jump test are excellent indicators of aerobic capacity, agility and explosive leg power, respectively

(Doug *et al.*, 2002). Figure 1 below indicates the interrelationships between the game of basketball, fitness testing, positional roles and the three components of physical fitness.

Physical fitness testing is helpful as it determines the level of the attributes required in a player as regards the position they play. One position would often require an emphasis on one component than the other and the acquisition of the correct combination by a player would lead to optimum performance through meeting the demands of that position (Wu, 1998).

1.7 Significance of the Study

This study evaluated selected skill related components of physical fitness in basketball players. It is expected that the study would give the players feedback on their fitness levels in relation to the positions played. Hoffman *et al.* (1996) examined the relationship of athletic performance tests, player evaluations and playing experience relative to playing time in 29 male division one-college basketball players. Their study demonstrated the important relationships between leg strength, vertical jump, speed and agility on playing time. Other studies have been conducted on offensive and defensive strategies in basketball (Wu, 1998) and energy systems in basketball (McArdle, Katch & Katch, 1996). However, a majority of the studies do not relate their studies to the specific requirements of the playing positions, hence the need for this study.

Sports like basketball that require more skill and endurance present the researcher with more complex problems, as the physiological demands and the fitness required in them are not easily determined (Reilly *et al.*, 1990). This study provided the coaches and trainers with a basis for the establishment of physical fitness norms in a team sport by giving physiological profiles of Kenyan basketball players in agility, leg explosive power and aerobic capacity. These norms could be used as criteria for selection and comparisons with international teams. According to Arnheim and Prentice (2002), basketball is a game that also demands optimal physical fitness levels. However, studies are yet to be done on the physical fitness levels of the Kenyan basketball players, particularly in the areas of agility, explosive leg power, and aerobic capacity, hence the need for this study. The findings from this study highlighted the values of these selected components for the male basketball players who participated in the 2005 Kenya Basketball Federation Premier League.

The various components of play in basketball have their own physical requirements, such as the ability to jump high, flexibility, agility and speed for movement around the court. The skills involved in each sport are quite specific, and success in one activity does not necessarily mean equal success in another. This study may provide a background to the trainers and coaches of basketball by indicating the specific requirements in the game of basketball as a result of the tests carried out on the selected components of physical fitness. The study aimed at providing the players, coaches and trainers with specific information as regards positional play. The physical and physiological profiles addressed in this study are helpful to coaches, trainers and conditioning coaches as they attempt to improve the functional abilities of their players. Specific conditioning programmes are implemented to enhance playing performance and to reduce injury. The data provided may also aid in the understanding of the physically challenging nature of basketball which is quite necessary for coaches as they train their players.

The Kenya Basketball Federation Premier League is the highest league tournament in the country and therefore serves the national team with most players. The study therefore provides feedback to the coaches and the players too at the national level, which serves as a guideline for further training. The study also benefits future researchers by giving a basis for further research on basketball players and also interdisciplinary comparison between various sports.

This study helped to establish how basketball players' fitness during the in season relates to the playing position by assessing the levels in agility, leg explosive power and aerobic capacity. The study also established physical characteristics of Kenyan male basketball players for use by coaches and researchers. Latin *et al.* (1994) looked at the physical and performance characteristics of National Collegiate Athletics Association (NCAA) Division One male basketball players with the aim of evaluating a physical fitness and performance profiles of the players. However, the study cited above involved collegiate players and did not use top-level basketball players. Also the study did not look at the differences in terms of the playing positions and therefore cannot be used to make inferences on top level competition and differentiation in playing positions.

1.8 Limitations of the Study

The study was conducted under the following constraints:

i) The researcher had no control over the training programme that the basketball players engaged in.

ii) The researcher had no control on the players' diet.

iii) The researcher had no control on the players' heredity.

1.9 Delimitations of the Study

The study was delimited to the following:

i) Male basketball players who participated in the 2005 Kenya Basketball Federation Premier League in Kenya.

ii) Assessment of the agility using the SEMO agility test, explosive power using the vertical jump test, and aerobic capacity using the multistage shuttle run test.

iii) Players' positional role in their teams.

1.10 Assumptions of the Study

The study was based on the following assumptions:

i) All basketball players in the sampled teams would be in good health.

ii) All coaches or trainers in the sample teams were qualified personnel.

iii) All the basketball players in the sampled teams would get adequate training.

iv) All the basketball players in the sampled teams would be regularly getting balanced diets.

1.11 Scope of the study

The study involved the male basketball players who took part in the National Kenya Basketball Federation Premier League in the year 2005.

1.12 Operational Definition Terms

Aerobic Capacity: - Maximum volume of oxygen consumed by the body each minute as implied by the number and level of shuttles completed during basketball while breathing atmospheric air as measured by the multi stage shuttle run test ($ml/kg.min^{-1}$).

Agility: - Physical ability, which enables an individual to rapidly change position and direction in precise manner while playing basketball as measured by the SEMO agility test which indicates the time in seconds taken to go through obstacles.

Basketball: - Game played by two teams each of five people in a court with the aim of scoring by throwing the ball through the hoops, in the Kenya Basketball Federation (KBF) 2005 premier league.

Basketball Player: - A male player who participated in the Kenya Basketball Federation (KBF) 2005 Premier League.

Centers – Players assigned to position number five on the court and designated the role of playing under the basket. The center jumps for the ball at the beginning of the game, and can almost always be found playing in and out of the circumference on offense and on defense. They are usually the tallest players in the team.

Endurance: - Ability to perform prolonged bouts of activity in basketball without experiencing fatigue or exhaustion as assessed by the multi stage shuttle run test.

Forwards – Players assigned to position number two on the court and designated with the role of scoring. They usually play on the circumference and corners and can be found driving along the baseline. They are usually the second tallest players in the team.

Guards – Players assigned to position number one on the court and designated with the role of initiating moves; normally they have excellent dribbling skills, and they usually play on the circumference. They are generally the shortest players in the team.

Heart rate: - Pace or frequency at which the heart beats per minute (bpm) while performing the multistage shuttle run test.

Playing Positions – Playing roles assigned to players on court during a basketball game. The positions are divided into guards, forwards and centers.

Vertical jump: - Maximum height that a player can jump vertically during a basketball game as measured by the vertical jump test in centimeters.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 Introduction

This chapter highlights the nature of the game of basketball as well as the importance of agility, aerobic capacity and leg explosive strength to a player during the game. The measurements of these variables are also discussed.

2.2 The Game of Basketball

Basketball is one of the fastest growing team sports in Kenya. It is also one of the most popular team based sports played and watched throughout the world (Wu, 1998). In Kenya, basketball is played at all levels ranging from high school to the Premier League, where the latter is regarded as the elite level. Basketball is a game played by two opposing teams on a court measuring 29 x 15 meters. The aim of the game is for each team to defend a goal area while trying to score goals at the opposing end of the court. Each team consists of ten players but only five of them may take the court at any one time during play.

The game of basketball includes a combination of technical and tactical abilities as well as a high degree of physical fitness (Smith and Thomas, 1991). Due to the variations in size, fitness level, specific techniques, defensive and offensive strategies, players usually are assigned to different playing roles and positions (Wu, 1998). Based on the players' specific roles on the court, each position generally would demonstrate a unique style of play at different spots of the court. For example forward players are usually the best scorers of the team, and should be involved in some rebounding and passing tasks. This is why most forwards need to possess great size, speed and leaping ability (Wu, 1998). However, the researcher did not come across any existing demographic and physiological data showing the characteristics of the Kenyan basketball players. The specificity in positions implies that different positions would have different requirements and as a result the training methods would target certain areas more than others depending on the positional role of the player. The three key positions in basketball are the Center, the Guard and the Forward. Each of these positions require different of fitness components (Wu, 1998). There is need to come up with the tests that indicate the differences in the requirements of the playing positions as well as assessing the physiological data of the Kenyan basketball player. The literature reviewed looked at the game of basketball in relation to the three playing positions in relevance to aerobic capacity, explosive strength and agility.

2.3 Measuring of Skill – Related Components in Basketball

For optimal performance during play at an elite level, a variety of areas must be addressed. These include a good skill level, flexibility, muscular strength, endurance and the specific use of both the aerobic and the anaerobic energy systems (McArdle *et al.*, 1996). Testing physical and physiological requirements for basketball has become more specific over the past decade. This has greatly been facilitated by further advances in sports science technology and general understanding of the physiological requirements in testing basketball (Scheller and Rask, 1993). Sports science and technology has advanced methods of physiological testing. This involves assessment of physiological status, which can be used as a measure of sports performance. Many factors contribute to the performance of the basketball athlete. These include a combination of technical and tactical abilities as well as a high degree of physical fitness (Smith and Thomas 1991). The critical factor in fitness testing is to test both the anaerobic and aerobic exercise systems while allowing for sports specific actions. Theoretically, testing procedures and results should also possibly consider the different player positions and requirements. To ensure that test results are all reproducible, a set of standardized protocols should be followed (Ellis *et al.*, 1998).

A multifaceted approach is generally utilized for elite basketball teams combining all aspects of the game. Anthropometry is used to provide a basis for training and dietary interventions. This includes measurements of age, height, mass and skin folds. Anaerobic performance tests are used to assess speed, acceleration, explosiveness and repeated short bursts of efforts, which are all important components of basketball. Variations of the vertical jump test (Isaacs, 1998; Stapff, 1998) are familiar tests within the literature cited to measure explosive strength in the legs. A more specific test to the game of basketball mentioned in the literature is the 20 meter sprint test. The test is relevant because the court's dimensions of 29 meters by 20 meters are normally the distance run in one burst. Other measures used with testing elite basketball teams are the 10 meter and 30 meter sprint test as noted by Isaacs (1998).

Aerobic capacity is mentioned as another important component of basketball. Continuous periods of effort are required throughout a full-length game and more so within a heavy training session, which must utilize oxygen for performance. The maximal oxygen consumption (VO_2 max) laboratory test and the 20-meter multistage shuttle test are the common tests for assessment of aerobic power (Scheller and Rask, 1993). Because basketball requires numerous skills, which must be applied dynamically, explosively and repeatedly strength of the arms and legs are both important to consider. However, much less is known about testing in skill related parameters for players in uninterrupted programmes. Groves and Gayle (1993) in their study assessed the strength training of basketball players. In this study they looked at 8 players only but did not relate their study to the positions played by the assessed players. Hoffman *et al.* (1996) examined the relationship of athletic performance tests, player evaluations and playing experience relative to playing time in 29 male Division One-College, basketball players. Their study demonstrated the important relationships between leg strength, vertical jump, speed and agility on playing time. They also found that upper body strength and aerobic endurance are important components of a basketball player's preparation.

According to Reilly *et al.* (1990), majority of the studies describing physiological and anthropometrical profiles of elite athletes have been concerned with runners, swimmers and cyclists. The bias of such individual studies is probably due to the comparative ease in relating such profiles success in these sports, where endurance performance can be measured precisely. The sports that require more skill and endurance are found to present the researcher with more complex problems, as the physiological demands and the fitness required in them are not easily determined. The various components of play in basketball have their own physical requirements, such as the ability to jump high, flexibility, agility and speed for movement around the court. Further more, since basketball matches last for

20 minutes and above, muscular and cardio respiratory endurance are also needed (Wooten, 1992). The skills involved in each sport are quite specific, and success in one activity does not necessarily mean equal success in another. In any case, it is impossible to measure all the specifics of complex physical activities. Thus an acceptable alternative has been to sample some of the specific traits involved in athletic performance (Getchell *et al.*, 1998).

In summary, the main reasons for testing are, to establish individual physiological data for routine reassessment, to review effects of training programmes and for identification of potential talent. However, it should also be noted that other teams have developed their own standard forms of protocol (Ellis *et al.*, 1998).

2.4 Temporal Demands and Physical Characteristics of Play in Basketball

Basketball is a game of high intensity activity interspersed with rest periods. Technical demands of the game and the tactical systems employed have led to players adopting specific roles during matches (Wu, 1998). This imposes particular requirements on these players. For instance, there are variations in size, fitness level, specific technique, and offensive strategies, which in turn lead to players being assigned to different playing roles and positions (Wu, 1998). The sections below indicate the demands and characteristics of play in the game of basketball.

2.4.1 Energy Systems

Reilly *et al.* (1990) argue that, the explosive nature of basketball with rest periods may seem to make it classified as a sport relying 95% on the Adenosine Triphosphate (ATP) – Phosphocreatine (PCr) system and 5% on the lactic acid system (La – O_2). Similarly, Black and Roundy (1994) described basketball as a game that derives 85% of its energy expenditure from the phosphagen stores such as Adenosine Triphosphate (ATP) and Phosphocreatine (PCr) and 15% of its energy from anaerobic glycogenolysis. These energy systems cannot provide all the energy if the game lasted for a continuous period of 20 minutes. It has been calculated that the phosphagen stores could provide energy for between 6 – 8 seconds, whereas anaerobic glycogenolysis could provide energy for about 60 seconds before high levels of lactic acid in the muscle induced fatigue. For 85% of the energy to be derived from phosphagens, and 15% from La – O_2 during 20 minutes halves, there should be periods of vigorous activities that are not longer than 20 seconds in duration followed by less vigorous or even rest periods to allow for phosphagen replenishment and oxidation of lactate (Doug *et al.*, 2002). However the 25 – 45 seconds rest periods between the high intensity performances are sufficient to replenish the ATP – PCr stores in muscles. Basketball is classified as a heavy activity in terms of its aerobic energy demand, (64.5 KJ per min) for a 70 kg person. The measured mean heart rates would be ranging from 170 beats per minute. While playing basketball, the demands would constitute a demand in excess of 70% VO_2 max for an elite basketball player assuming that the person has a VO_2 max of 60 ml/kg/min (Reilly *et al.*, 1990).

The mean heart rate values for female basketball players in the study by McArdle *et al.* (1996) varied between 154 and 195 beats per minute. The heart rate while playing was approximately 81 – 95% of the maximum heart rate. Estimated energy expenditure for these female players was 29.82 – 49.56 KJ per minute. This supports the contention that, basketball is a moderately heavy activity. Doug *et al.* (2002) studied heart rate response of a male basketball player, whose rates varied within 155 – 190 beats per minute. An interesting finding in this study was that even during rest periods, such as time outs and fouls shots, the heart rate did not decrease below 155 beats per minute.

Studies on the muscle glycogen depletion have highlighted the importance of carbohydrates as an energy source during exercise and further point to the use of specific muscle fiber types during such activity. Reduction of muscle glycogen stores has been correlated with fatigue in laboratory investigations and with reduced performance in the field (Jeremy *et al.*, 2004). Physiologically basketball requires energy from both the aerobic and anaerobic energy systems and this combination of energy requirements is often referred to as an integration of energy supply systems on a continuum over time. Basketball is also highly specific and the specific requirements do vary depending on the level of competition. In Australia, the elite Men play twelve-minute quarters, which are fully timed while the females play twenty-minute halves, which are also fully timed. Both competitions entail a half time rest period of between 10-15 minutes with the men also having a five-minute rest period at the end of the first and third sessions. Both competitions allow 4-5 time out sessions per game lasting 3 minutes. These many time outs, short half breaks and stoppage in play all lead to better recovery time for the basketball players throughout the game (Doug *et al.*, 2002).

In the game of basketball, only 5 players in a team play at any one time. However, play is characterized by various intensities and durations. McInnes *et al.* (1995) analyzed the active time of play defining this as "live" time, which was found to be 54% of the total game time. There are several categories noted by McInnes *et al.* (1995) revealing the varying levels of exercise intensity throughout a game. The varying levels of exercise intensity and duration relate specifically to the two energy systems providing energy to the athlete. The first system, namely the anaerobic supply involves the delivery of energy for physical activity at a high rate, without oxygen but it only has a limited time of supply. This anaerobic system can be classified into the ATP-CP (adenosine triphosphate - creatine phosphate) and the lactate systems (McArdle *et al.*, 1996). The ATP-CP system provides immediate energy for quick bursts of activity such as driving to the basket, jumping, shooting, dribbling and rebounding. McInnes *et al.* (1995) also note high intensity run efforts occurring on average once every 21 seconds during "live time" for a 1.7 second duration which is similar to the 1- 4 sec reported by Macleod (1993). This short burst of energy (2 - 4secs) is fueled by the breaking of high level energy phosphate bonds as ATP is changed to ADP. When used maximally, however, this system is limited to approximately 10 -15 seconds (McArdle *et al.*, 1996; Sheller and Rask, 1993; and Stone and Steinguard, 1993). However, it is notable that the game of basketball does often require high intensity periods of work longer than the amount provided for by the anaerobic system. This allows the use of the second category of fueling system namely aerobic system.

A series of fast breaks or fast paced passages of play result in the athlete calling on the anaerobic lactate metabolism (Stone and Steinguard, 1993). This involves anaerobic glycolysis to release ATP and produce lactic acid. These anaerobic energy sources are rapidly replenished in the recovery periods. Recovery from maximal effort using the ATP - CP and lactic system can approximate 3 minutes and up to one hour respectively. The more prolonged recovery with the lactic system is due to the elevated levels of blood lactate (McArdle *et al.*, 1996; Stone and Steingard, 1993). The more intense the work periods and the shorter the recovery periods the greater the aerobic contribution to maintain performance (McArdle *et al.*, 1996).

2.4.2 Characteristics of Basketball Players

a) Height and Weight

Unique types of body size and proportion may constitute important prerequisites for successful participation in particular sports. Wu (1998) asserted that although an ideal physique was not mandatory in itself for excellence in a sport, its lack even in the presence of compensating attributes might be a severe handicap to a potential athlete. Such statements can be suitably applied to sports such as basketball.

Examinations of heights and weight of elite basketball players highlight the fact that, the players are fairly tall. Recent research on elite basketball players has illustrated the development of the trend towards an increase in height and the variation in height for positional play in basketball. The shorter the player, the higher he has to jump in order to play successfully in the aerial zone. Indeed if the player were too short, he might then not be physically able to reach the necessary heights despite a good vertical jumping ability (Jeremy *et al.*, 2004). Wootten (1992) indicates that elite basketball players are even taller than the volleyball players, especially the centers and forwards. This physical attribute is particularly important when it is realized that the game involves physical contacts with the intention of getting the ball in a "basket" elevated 10 feet (3.05 meters) above the ground level. Wu (1998) concludes that certainly in professional basketball, centers and forwards are unlikely to be selected unless they are in excess of 2 meters in height. He further argues that height and good jumping ability would be essential prerequisites for participation at elite levels.

Most elite basketball players have tall, muscular, well-balanced physiques (Smith and Thomas, 1991). However, the players do have varying anthropometric variables depending on the position of the player. A review of team dynamics, on the court indicates a team consisting of 2 forwards, 2 guards and a center with each player having to play in attack and defense. In analysis, the forwards tend to be taller and heavier compared to the guards who are shorter and lighter. The center is, however, normally the tallest player in the side with the greatest arm span and reaching ability, which is required in both the defensive and attacking roles. The centers are required to utilize their height to the greatest benefits of the team in such skills as rebounding, defensive blocking and jump shooting. The guards tend to be the starting point of attacking patterns. This requires them to control and dribble the ball up the court. They generally stay further away from the basket than the forwards. The forwards perform some dribbling skills but are expected to help guards in setting up attacking patterns while also defending and rebounding close to the basket (Stone and Steingard, 1993).

Mean heights recorded for elite senior female players are 1.89, 1.81 and 1.72m for the centre, forwards and guards respectively (Stone and Steingard, 1993). This indicates the obvious differences between positions. The average team heights for female and male Australian Institute of Sports players is 1.80m and 1.99m, respectively indicating significant differences not only between team players but also between different genders. Data according to the Australian Sports Commission (1998) indicate a mean height of 1.98m for the centers, 1.89m for the forwards, and 1.74m for the guards during the 1994 Senior Female Basketball World Championships. The average weight for the male senior players during this competition was 94.6 kg with a mean age of 18.4 years. The average skinfold measurement was recorded at 72mm.

Height certainly appears to be a critical component of potential performance, which is more relevant for the center and forward positions. The guard position generally requires greater emphasis on ball handling skills including passing and shooting (Miller and Bartlet, 2002). The literature reviewed indicates that the shorter and lighter stature of the guards gives them greater speed and agility to fulfill their requirements. However, there are no data available showing the normative scores for players as regards their positional roles. Such information also lacks in the Kenyan setting. This is however important to consider when reviewing fitness tests. There is limited anthropometric research data on shooting performance apart from those of Miller and Bartlett (2002) which suggests that guards can more easily make kinematic shooting adjustments compared to the forwards and centers.

b) Body Composition and Physique

Elite male basketball players, in keeping with many other elite athletes tend to be lean and muscular. This is reflected in the measurement of percent body fat of basketball players from 7.1 – 13.5%. It is, however, notable that although these figures are useful in providing reasonable guidelines for percent body fat, caution must be expressed when interpreting such data due to the variations in the methods of assessing body fat (Doug *et al.*, 2002).

The physique of these athletes have also been determined and expressed as endomorphs, mesomorphs and ectomorphs ratings. Mean values in the literature on collegiate teams in basketball indicated the following; 2.5: 5: 3.5 possessed by endomorphs, mesomorphs and ectomorphs, respectively. These results reinforce the belief that being lean and masculine are requisites for playing basketball at a higher standard. In fact, body fat measurements of elite level basketball players suggest a leaner body type as compared to the normal population. Skinfold measure is the major determinant of body fat and is generally used as a basis for training and dietary interventions. As basketball is a sport requiring speed and explosive power, excess fat is also undesirable as it will be detrimental to performance (Doug *et al.*, 2002).

2.5 Agility and Basketball

It is more likely that agility is highly task specific. This means that one's performance on the shuttle-run test might not reflect how well or poor one would perform on another agility test (Bergemann, 1999). Numerous investigators have indicated the importance of agility as a factor in prediction of motor ability and or sports ability. In fact Jeremy *et al.* (2004), argue that agility seems to be fundamental to skill in certain sports activities. In their studies they found that agility is important to basketball performance.

Jeremy *et al.* (2004), in testing primary grade children, found a moderately high positive correlation between physical growth and ability performance in boys and girls. They noted that both boys and girls increase in agility performance up to fourteen years of age, after which girls seem to decline while boys rapidly gain in agility performance. Concerning body types, there is general agreement among investigators that endomorphs (fatty types) have the least potential of the somatotypes concerning the performance in agility tests. However, some disagreements exist concerning whether mesomorphs (muscular type) are superior to ectomorphs (thin type). In this view the guards tend to be leaner and lighter than the forwards and the centers in basketball and one would expect them to score higher in agility tests (Doug *et al.*, 2002). Among the literature reviewed there were no normative data documented on agility in relation to basketball fitness testing. This is partly due to the different types of methods used to assess agility that resulted in different scores and this is a clear indication of the specificity of agility tests to the game and the test used.

2.5.1 Agility Development

For many years, physical educators and coaches generally felt that muscular development associated with weight training was harmful to skill coordination. However, in recent years investigators have elicited results, which indicate that progressive resistance exercises tend to affect favorably the coordination of performers (Johnson and Nelson, 1991). In the past, it was generally believed that agility was almost entirely dependent upon one's heritage. However, research has revealed that it could be improved through practice, training and instruction (Macleod *et al.*, 1993). Specific training directed towards the sudden change of direction could be used to improve agility.

2.6 Aerobic Capacity and Basketball

Cardio-respiratory endurance forms the foundation for the whole body fitness. It increases the capacity to sustain a given level of energy production for a prolonged period. Development of cardio-respiratory endurance helps the athletes to work longer and at greater levels of intensity. Elite basketball players require a high level of aerobic fitness and optimal body composition profiles in order to maximize performance (Jeremy *et al.*, 2004). This is clearly detailed in the preceding discussion on energy systems.

2.6.1 Factors that Determine Aerobic Capacity

Cardio respiratory endurance depends on the ability of the heart to pump blood, the lungs to inhale volumes of oxygen and the muscles to utilize this oxygen. Therefore, sustained muscular activity is possible only through the effective functioning of these body structures. Various tests involving vigorous physical movements that make increased demands on the heart and lungs have been devised to assess cardio respiratory endurance. Aerobic endurance involves moving large muscle groups repeatedly for 3 minutes or more, but preferably more than five minutes. The limitations in performance are primarily the oxygen delivery system and at the cellular level (Reilly *et al.*, 1990).

2.6.2 Evaluating Aerobic Capacity

Procedures for determining aerobic capacity in the laboratory are complex, time consuming and impractical for testing large numbers of people. Recent studies, therefore, have attempted to develop field tests that can be substituted for laboratory tests like the Harvard Bench Test, the Cooper 12 Minute Test, the Rock Pot test and the 1.5 Mile Run Test. Researchers have tried tests like the 1.5 Miles Run, Step Test and Multi Stage Shuttle run all of which have correlated well with laboratory-determined values for cardio respiratory endurance. The field test makes it quite easy to determine aerobic capacity and detect changes due to training (Bergemann, 1999).

2.6.3 How to Improve Aerobic Capacity

Aerobic training programs are designed to improve cardiovascular function as well as the efficiency with which the body is able to utilize oxygen. The cardiovascular system includes the heart, lungs and blood vessels. Aerobic activities significantly raise the heart and respiratory rates and should last for 20 minutes or more to produce a conditioning effect (Macleod *et al.*, 1993). The time factor is the crucial element since one must breathe in oxygen and transport it to the working muscles. Overload is a basic principle of conditioning. The body must work beyond its normal demands to increase efficiency. Aerobic training programs gradually force the body to exercise for longer periods of time and with more intensity. Reilly *et al.* (1990) suggest that full court basketball is a good sport for developing muscular and cardiovascular endurance. Thus, coaches and trainers have devised drills on the court that work on the aerobic capacity of the players. These exercises range from running to dribbling exercises with different variations.

2.6.4 Multi Stage Shuttle Run Test

The 20-metre Multi Stage Shuttle Run Test was used as early as 1982 by Leger and Lambert (1982) to test aerobic power. It was found to be an accurate estimate of maximum aerobic capacity measure (VO_2 max) (McNaughton *et al.*, 1996). It is thus a good test to use due to its many advantages.

The main advantage of the test is its simplicity. As outlined in its procedures, it requires minimal equipment and as a result is very inexpensive. The test is very versatile and can be performed indoors or in the field. However, to aid reliability and specificity it is best tested on the basketball court. The fact that the shuttle run is a field test, it then lacks the reliability of the laboratory tests. However, the environment is more sports-specific making the test more valid (Stapff, 1998).

Another advantage is that the test can be performed in large groups, which aim to stimulate competition and help establish a maximal effort. The progressive nature of the test involving the slow starting speed allows an appropriate warm up within the test itself. The change of direction with turning and pushing off to accelerate is highly relevant to basketball due to the quick bursts of speed and change in direction required within the game (Stone and Steinguard, 1993). This change in direction component of the test has created some discussion due to anaerobic component. Grant *et al.* (1995) described the turning component of the test and the acceleration or anaerobic component contributing to the overall result and thus not indicating a true measure of pure aerobic power. He describes that a person with low anaerobic power may actually under perform in the Multi Stage Shuttle Run relative to their aerobic power. Despite this argument the correlation between the test and the direct measure of VO_2 max is good amongst many studies ranging from 0.83 - 0.91 (Grant *et al.*, 1995 and McNaughton *et al.*, 1996).

In summary the 20-metre Multi Stage Shuttle Run Test has been regularly used as a measure of aerobic fitness in basketball players at the highest levels. The shuttle test scores are often, however, used more accurately for inter and intra athlete comparison rather than the comparison of this VO_2 max gained from the scores.

2.7 Explosive Strength and Basketball

The evaluation of performance characteristics in athletes is a common practice. In basketball, an important measurement taken regularly is vertical jumping height. Previous research has shown that there is a strong correlation between vertical jump ability and explosive leg power. Recent methodologies in measuring jumping performance involve the use of force plates or contact mats and electrical timers (Harmen, 1991). Other methods of testing power in the lower body include cycle ergometer tests, countermovement jumps, static jumps, force platforms, short sprints, maximum weight lifts, leg press, standing broad jumps as well as isometric and isokinetic tests. The basic counter movement Jump, or 'Sergeant Chalk Jump Test' is the vertical jump test most often referred to in current literature which, Johnson and Nelson (1998) report to have a leg power reliability of 0.93 and a validity coefficient of 0.78. The objectivity of the test is reported to be 0.93.

Explosive power comes from the development of speed strength and pure strength. Power represents the amount of work a muscle or muscle group can produce per unit of time (Adams *et al.*, 1992; Duke and BenEliayhu, 1992; and Lyttle, 1994). Until recently, power as it relates to sports performance was a subject of limited research. However, in the last decade, researchers have realized the importance of training for power in a wide variety of sporting activities (Wilson *et al.*, 1993).

Vertical jumping, in its many different forms, requires high levels of explosive muscular power. Basketball players typically jump from one foot to perform a lay up, and from two feet to rebound jump. Both of these are very different styles of jumping, which are fundamentally similar in their movement patterns (Harmen, 1991). Different jumping styles also involve very different approaches and run ups, which increase or decrease the velocity of the movement performed, depending on the type of jump. It has been suggested that different styles of jumping require different strength properties and that training for one type of jumping technique will not necessarily improve performance in another style of jumping (Young, 1995).

There have been many research studies that have investigated leg power as it relates to vertical jump (Harmen, 1991; Young, 1995). A number of other studies have investigated how to develop leg power through various weight training (Adams *et al.*, 1992; Duke and BenEliayhu, 1992), as well as plyometric training techniques (Adams *et al.*, 1992). Data has been produced for many elite individual and team sport athletes on physical and physiological characteristics, including standing vertical jump scores related to specific sports performance (Black and Roundy, 1994; and Latin *et al.*, 1994). There is limited research available, however, comparing athletes in relation to the playing positions of different sporting disciplines in vertical jump ability. Such studies if carried out would explain why athletes in some sports perform better at vertical jump than athletes in other sports especially in sports that require a substantial jumping ability such as basketball.

2.8 Factors Affecting Vertical Jump Ability

There are several factors, which affect the ability of an athlete to successfully perform a standing vertical jump. These factors can be identified by physiological and other sports testing procedures. The specific composition of muscle fibers of the individual athlete will affect the development of power and athletes with a high percentage of fast twitch muscle fibers are able to develop greater amounts of explosive power (Wilson *et al.*, 1993).

The initial levels of strength of the athlete and the ability to make use of a Stretch Shorten Cycle will also effect development of power (Adams *et al.*, 1992; Duke and BenEliayhu, 1992). Athletes who are trained in jumping techniques such as in the games of basketball and volleyball should be able to utilize a much more forceful pre-stretch for production of an efficient stretch shorten cycle than untrained athletes. This implies that trained athletes are able to mobilize the required muscle fibers in readiness for the jump as compared to the untrained athletes or athletes whose sports do not require jumping techniques. The possible existence of two different types of stretch shorten cycle has also been suggested by Young (1995). A long stretch shorten cycle and a short stretch shorten cycle, which are developed by specific types of training, and are mutually exclusive of each other. The use of elastic and contractile energy for producing dynamic muscle contractions as required in maximum power sports has been well documented (Adams *et al.*, 1992; Duke and BenEliayhu, 1992).

Other factors, which have been shown to affect vertical jump performance, are effective use of the arms for increased vertical velocity (Harmen, 1991), trunk extension; head movements and utilization of a countermovement (Harmen, 1991; Young, 1995). These actions are a natural movement during a jump for most athletes; however, they occur in different degrees between jump trained and non-jump trained subjects.

Upper body and abdominal (trunk) strength has also been shown to be a contributing factor to vertical jump performance. Strength in the upper body, particularly the arms and shoulders help to increase the stability throughout the trunk region, creates a solid posture to help maximize jumping technique, and also to maximize power production and transferal of forces between the upper and lower body. The fact that an arm swing is so important to vertical jumping performance may indicate that there is a technique or skill component to vertical jumping, rather than just leg power (Young, 1995). If this is true then the development of a motor pattern for vertical jump will also be a factor affecting performance in vertical jump testing of athletes.

In relation to the specific composition of muscle fibers, it has been suggested that athletes with a well-developed anaerobic power capacity will generate more power than athletes with a high aerobic power capacity (Latin, 1994). The components take-off height, flight height and reach height all play a role. By fully extending the body at the instant of take-off, therefore lifting the center of gravity at take-off may lead to an increase of several inches vertically. Similarly, flight height and reach height can further contribute to jump height, through means of increasing velocity of the flight at take-off and by body orientation, respectively. Latin (1994) also acknowledges the role of the arm swing and the lower extremity in the propulsion of the body in the jump. It is identified that there is an individual, optimal combination of speed and strength in relation to maximum vertical jump height (Young, 1995).

2.8.1 Methods of Developing Explosive Strength

There have been many different methods and training techniques utilized in various research studies investigating the development of explosive strength. Resistance training is a common term for many different types and variations of exercises using various resistances. These resistances overload the musculature to provide a training effect

(Lyttle, 1994). Plyometrics are a training technique, which utilizes the stretch, shorten cycle to produce energy for dynamic muscle contractions, and are said to be vital to the optimal development of muscular power. Other forms of training commonly used to develop explosive strength include various combinations of resistance training and Plyometrics, short sprints, towing sleds, maximum vertical jumping, medicine ball drills and other training methods (Adams *et al.*, 1992).

Lyttle (1994) summarizes the various techniques used to develop explosive strength as follow:

i) Traditional heavy weight training.

ii) Explosive lightweight training.

iii) Plyometrics.

iv) Combined weights and Plyometrics.

v) Maximal power training.

There have been numerous studies investigating the effects of weight training on power development (Adams *et al.*, 1992; and Duke and BenEliayhu, 1992), and plyometric training (Adams *et al.*, 1992 and Duke and BenEliayhu, 1992), while limited research has been carried out investigating the combined effects of plyometric and weight training on vertical jump ability (Duke and BenEliayhu, 1992). Much of the research data comes from authors who use subjects who come from jumping oriented sports (volleyball and basketball), but do not relate or apply the results of their research directly to playing positions in these sports. However, these training techniques can be applied to many sports, which require high levels of explosive leg strength as a major physiological component for optimal performance (Lyttle, 1994).

Other studies have suggested that plyometric training techniques used by themselves only or in conjunction with resistance training is no more effective than just resistance training techniques alone (Wilson *et al.*, 1993). Most available literature examining muscular power development has dealt on the acquisition of lower body power. Therefore, the relative success of upper body power training is unclear, and its effect on lower body power development is still relatively unknown. The lack of research in this area has been attributed to the difficulty in accurately assessing upper body power and performance, and also the fact that the majority of sports are lower body dominated. It has been shown however, that upper body movements and trunk stability are important factors in the development of explosive power and vertical jump (Latin *et al.,* 1994).

As vertical jumping is involved in most sports to a greater or lesser extent, most coaches and conditioners of team sport athletes would employ some or all of these techniques alone and in combination with each other depending on the demands of the specific activity and the phase of training. However, the specific requirements of the sport and more so the players playing positions or roles on the court should be kept in mind to determine the appropriate training techniques to apply (Young, 1995).

It is difficult to compare and contrast the results of the various studies, which have been published, as they all vary greatly in the application of training techniques, duration of research, testing procedures utilized and the general experimental design. However, reference has been made to several limitations in applied strength training research which could easily be applied to the majority of the available literature on power training research, which influences the validity of the conclusions drawn from the research (Wilkes, 1995).

Latin *et al.* (1994) indicate that jumping exercises and plyometrics enhance performance in strength-speed sports because they increase leg power and train the nervous system to activate large muscle groups when one moves. In a study conducted by Wilson *et al.* (1993), researchers suggested that leap training utilizing a swimming pool and jumping plates safely improved the leaping ability of elite gymnasts. In the study, after one month of training, gymnasts improved their explosive power by 220%, ground reaction time by 50%, and leap height by 16.2%. This type of training could be borrowed for other sports like basketball to improve the jumping ability.

2.8.2 Factors Affecting Development of Vertical Jump

There are several factors, which influence the success of a program to develop lower body muscular power, both in the short term and over a longer period of athlete development. Vertical jump ability depends on the capacity of the anaerobic energy system to produce maximum amounts of force as quickly as possible. It has been shown that any aerobic type endurance training or repeated exposure to aerobic type activities produces changes to the overall aerobic energy system. These changes have been shown to have a negative effect on anaerobic power production capacity. Therefore, concurrent training on both energy systems interferes with the development of each of these systems individually. Coaches and conditioners of team sports such as basketball, hockey and soccer, need to address this problem and design the training programme to minimize the negative effects of concurrent aerobic and anaerobic training. This would require a balanced training programme to cater for the specific sport and more so to the requirements of the position being played (Young, 1995).

Young (1995) argues that the specificity of the movement patterns in the sporting performance compared to the movements required in a vertical jump, will also affect the ability of an athlete to vertical jump successfully. That is, if the athlete is normally required to jump from one foot using a run up then a two footed standing vertical jump may not be an accurate test of jumping ability or muscular power. Similarly if the athlete has to hold a ball or piece of equipment in their hands while executing a skill, a standard vertical jump may not accurately reflect their vertical jump ability.

The overall amount of jumping performed by the athlete in training and in competition will influence the development of 'jumping technique', and the efficient use of a stretch shorten cycle to produce a good vertical jump performance. It has been suggested that the utilization of the energy available in a stretch shorten cycle can be trained for, but that is a separate strength quality in itself, unrelated to other qualities. Specific jump training and depth jumping techniques have been developed for training of this specialized strength quality (Young, 1995).

Continual development and maintenance of general and specific strength is important for the long-term development of vertical jump performance (Bobbert, and Van Soest, 1994). Therefore, periodisation of the overall training programme is vital in maximizing the desirable training effects and minimizing the interference of other negative training effects (Lyttle, 1994).

2.8.3 Differences in Vertical Jump Performance amongst Players in Team Sports

The available documented research investigating this area is fairly limited. However, it is possible to examine the physical and physiological demands of various sporting activities and to attempt to predict the effects of these upon a program designed to develop vertical jump ability. Research has shown international basketball players do rely primarily upon their anaerobic energy system to supply energy demands during a match. However, matches can last up to two and a half hours implying some aerobic component must be present as well. Elite basketball players typically show muscle fiber percentages of around 52 - 60% fast twitch muscle fiber composition. This compares favorably to samples from elite level sprinters and jumpers who have been found to have 45 - 80% fast twitch fibers (Bobbert, and Van Soest, 1994).

Elite basketball, football, hockey and soccer players would spend a majority of their time while training developing the aerobic qualities of their sports. Concurrent training for power and endurance are not compatible and negatively affects the development of each quality individually. For elite level basketball players, training and competitions primarily comprise short duration, high intensity work efforts interspersed with relatively short rest periods. High repetition jumping is not a characteristic of training and competition for basketball players, especially as compared to volleyball players who make use of several different jumping techniques, during spiking and blocking (Bobbert, and Van Soest, 1994).

Basketball in nature is characterized by work periods that are usually longer than rest periods and the overall distance covered in a game is much longer and this is reflected in the type of training these athletes commonly do. Basketball players do lots of jump training, because basketball requires the athlete to carry a ball, often take off one foot and often without full use an effective arm swing as compared to a game like volleyball. These athletes are generally exposed to less jumping in training and competition, compared to volleyball players. Basketball requires a much larger aerobic component, thus producing a training conflict between power and endurance. Athletes in other activities such as soccer and hockey, where jumping is not a primary skill, develop leg power specific to their sport through exposure to intense competition and various training techniques. Therefore, a standing vertical jump test may not be the best indicator of leg power for these athletes (Young, 1995).

Young (1995) has divided stretch shorten cycle movements such as jump take offs into two categories according to ground contact times:

- Long stretch shorten cycle - greater than 0.250 seconds such as in a Volleyball block jump.
- Short stretch shorten cycle - less than 0.250 seconds such as in a High jump take off.

He claims that it is possible for an athlete to excel at long stretch shorten cycle type activities without being proficient in short stretch shorten cycle movements and visa versa. This suggests that jumping abilities are extremely sport specific. He also suggests that standing vertical jumping as seen in a jump short in basketball (long stretch shorten cycle) may be dependant on different strength qualities compared to a basketball lay up take off, which involves take off using one foot. This involves a short ground contact time and a relatively small knee bend. Literature has also indicated something regarding the differences in 'jumping skill' between different jumping techniques, which are referred to as a 'critical timing'. Critical timing relates to the timing of the sequencing of the movements required to execute a skill. That is a high jumper must develop critical timing to transfer horizontal velocity into vertical height, and this is a major part of the skill. Factors that may affect training gains from drop jumping include the level of skill or training of the subjects at the start of the drop jump training program, the technique used in performing drop jumps, and the amount and type of training and playing activities in which the subjects engaged besides their drop jump training exercises (Young, 1995).

2.8.4 Factors Determining Jump Height

It is generally acknowledged that athletic achievement depends on both the properties of the musculoskeletal system and the control of this system. The control of the musculoskeletal system popularly referred to as co-ordination, timing, or technique, directly depends on the amount of stimulation each muscle receives from the central nervous system as a function of time. The properties of the musculoskeletal system include anatomical characteristics such as mass distribution and movement of arms muscles, biochemical characteristics such as enzyme activities and substrate concentrations in muscles as well as physiological characteristics such as muscle strength and muscle fiber type composition. Broadly speaking, the anatomical characteristics of an individual may predispose an athlete for success in sport, but they cannot be changed. The physiological and biochemical characteristics of muscles, however, are responsive to training and specific training may improve the targeted component (Lyttle, 1994).

A second major finding is that maximal jump height depends strongly on muscle strength. In order to gain jump height, increases in muscle strength need to be accompanied by maximization of control. Muscle strength determines the maximal jump height, which can be achieved, but control determines the actual jump height realized. It seems that drop jump exercises may provide the "overload" required for strength training. Drop jumping technique has an important influence on muscular performance and presumably on the training stimulus. To achieve a high muscular performance, the subject should be instructed to make the transition from landing to push-off as fast as possible. Increasing drop height has little effect on muscle forces, other than increasing the load on the skeletal system (Bobbert, and Van Soest, 1994).

Jumping is an explosive activity, the control of which cannot depend on neural feedback during the movement. The reason is that the delay time between the generation of action potentials in receptors and adjustment of muscle forces, let alone adjustment of speed and position, is far too large compared to the movement frequencies. Most likely, control depends on pre-programmed muscle stimulation patterns in combination with visco-elastic muscle properties acting as a zero-delay peripheral feedback mechanism (Lyttle, 1994). It is quite conceivable that these muscle stimulation patterns are stored in the weights of synaptic connections in neural networks. When triggered such networks "blindly" re-generate the stimulation pattern. Optimization of control would then involve the process of adjusting the weights of the synaptic connections in numerous practice trials. Since jump height depends heavily on a precise tuning of muscle stimulation patterns to properties of the musculoskeletal system, the stimulation patterns generated during the practice trials should match as close as possible those generated for the target jumps, or the jumps in which achievement is to be improved. The closest match obviously occurs when the practice jumps are identical to the target jumps. The target jumps are usually standing height jumps (counter movement jump), which are very different in kinematics from drop jumps. Since different kinematics are caused by a different control, drop jumps seem to be unsuitable as exercises for training control in standing height jumps (Young, 1995).

2.8.5 Vertical Jump Test

The jump is an explosive motor task used commonly throughout the game of basketball in many different forms (Stone and Steingard, 1993). Thus, the jump test is used as a measure of anaerobic strength of the legs. The vertical jump test is a widely used laboratory test mainly due to the frequency of the jumping action seen within many sporting activities. It is a test that has existed for many years since 1921 when the Sergeant's Jump test was used for the first time. Small modifications to procedures have been made since then. However, ultimately the basic concept remains.

The vertical jump is a cost effective and simple test, which is very specific to the requirements of basketball, which require jumping in all aspects of the game. The main skills involving jumping include the lay up, jump shot, rebound, shot block and intercepting passes. McInnes *et al.* (1995), note that high intensity type activities like jumping occur approximately 15 % of the total active time. Therefore, the vertical jump test can be used effectively as a measure to demonstrate changes from either jumping specific training or a specific lower limb strengthening exercise program (McArdle *et al.*, 1996).

One criticism of the vertical jump test is that it suggests to measure the explosiveness of the leg musculature. The inclusion of the arm swing in the test procedures does complicate the specific testing of leg power as the arm swing is thought to contribute approximately 10% to the jump height. The extensor muscles of the hip, knee and ankle are still the main contributors to this action and the vertical jump tests of muscular function are significantly related to dynamic performance levels (Wilson and Murphy, 1995).

To improve the specific measure of leg power an alternative test using the counter movement jump can be administrated as it eliminates the arm swing and places more focus on the leg muscles. This jumping action is not very game specific and is not currently used by the Western Australian Institute Basketball or the Perth Wildcats basketball teams (Ellis *et al.*, 1998).

Young *et al.* (1997) note the importance in establishing a test, which is specific to the sport. The difficulty with basketball is the variety of jumps that exist including single and double leg take offs, with or without a run up. Thus, Young *et al.* (1997) presented a board technique where the measuring board was placed on the basketball backboard and a test similar to the vertical jump of measuring vertical height was applied. The test appears more specific to basketball though some difficulties were established in the results. Some people found it difficult to achieve a vertical arm position when reaching up the board and others noted some intimidation or fear of injury when jumping to reach up onto the board with a run up. The test indicates the need for more specific related tests for basketball jumping. Young *et al.* (1997) also revealed that there is an optimum run up length and speed, which was found as 3 - 5 strides within the study for the double leg-take off. This information must be considered in the planning of future jump tests.

Another jump test commonly used is the Vertec, which is a vertical pole to which is attached small markers, placed 0.5 inches apart. This enables the athlete jump straight upwards and knock the highest possible marker to obtain a score. This eliminates the need for chalking the fingers and takes away the potential interference of the nearby wall as used in the vertical jump test (Isaacs, 1998 and Young *et al.*, 1997). The interference of the wall is minimal but may be likened to game situation where the jump has to occur amongst opposition players. This may be looked at as another positive aspect of the test often overlooked.

Other more sophisticated tests are also used to calculate jump height such as the use of force platforms requiring technologically advanced equipment. Isaacs (1998) describes the "Just Jump" system, which uses airtime to calculate jump height using specific technology. When compared to the Vertec jump test they both produced acceptable measures of jump height. However, due to its time efficiency, the Just Jump system was suggested. Despite the variety of tests that exist to measure jump height the vertical jump test does provide a reliable and sport specific measurement for basketball (Isaacs, 1998).

2.8.6 Limitations of Available Literature

As with most scientific investigations there are various limitations, which affect the validity of the results and the application of these results to populations outside of the specific experimental groups. Available literature investigating the present topic is inconclusive, inconsistent and relatively hard to come across.

There have been numerous studies, which have investigated leg power in athletes from various sports, in an attempt to examine responses to training and competition. Many of these have used vertical jump to test their protocol. However, very few studies have taken a broad cross section of elite athletes from lots of different sports to compare them in all areas relating to explosive leg power and jumping abilities. Research such as this could help investigators understand the reasons why differences exist between athletes in vertical jumping especially athletes playing in the same team in various positional roles, and also how to test more accurately the specific qualities exhibited after many years of specialized training.

Generally the available research, which relates to this topic, has its limitations in that there are no standardized experimental procedures and the testing protocols. Tests, which have been shown to be poor indicators, are still used to get results and to prove what they set out to achieve. Wilkes (1995) refers to several limitations in applied strength training research which can be applied to many of the research studies published in applied power training research as cited in this review. These limitations greatly influence the validity of any conclusions drawn from the results. Below are some of the limitations outlined:

1) Short study periods: - Applied studies are typically short term, 6 - 8 weeks generally which is not recognized as being long enough to draw conclusions from. Repeated observations or long-term programs may achieve different results which are generally far more reproducible.

2) Unrepresentative subject groups: - The experimental design of most studies uses too few subjects to be able to generalize from the results. Subjects may be inexperienced or elite, and will vary in their response to exercise. Results of tests and training methods on elite athletes can't be transferred across to non-elite athletes and vice versa. Many of the studies did not appear to consider the training backgrounds of the subjects involved and the types of activities they were involved in.

3) Absent or inadequate group comparisons: - Some studies often neglect a control group to compare the effects of the independent variable; therefore the dependant variable could have been influenced by anything. It is also questionable as to whether the researchers ensure that subjects in each experimental group are equally distributed in relation to training background, strength levels, etc.

4) Inadequate dependant variables: - Many studies implement poor testing procedures to assess the effect of the independent training variables. Vertical Jump has been shown to correlate strongly with measures of muscular power, but some of the other tests utilized in the literature under review here have been shown to be poor measures of testing muscular power of the lower body. i.e. 50 yard dash, isokinetic tests of leg strength, and standing broad jump.

Due to the general lack of research investigating this area, for the purposes of this study, therefore, there is an identification of recognized factors, which affect vertical jump ability, and an attempt to compare these with physical and physiological characteristics of elite basketball players.

Overall the major limitation with regards to the current research in this area is that there appears to be a major shortage of studies comparing normative data on vertical jump performance in attempt to explain differences in specificity of athletic ability.

2.9 Related Studies in Physical Fitness and Basketball

There are various studies indicating physical fitness parameters in the game of basketball. For instance, Hoffman *et al.* (1996) have examined the relationship of athletic performance tests, player evaluations and playing experience relative to playing time in 29 male division one-college basketball players. Their study demonstrated the important relationships between leg strength, vertical jump, speed and agility on playing time.

2.9.1 Basketball Studies in Relation to Positional Roles

Studies have been conducted on offensive and defensive strategies in basketball Wu (1998) studied the individual offensive strategies of Taiwanese collegiate students in basketball based on the role of the position played and recorded significant differences that existed among subjects' choices on offensive strategies depending on the position played. The study indicated that the number-one offensive choice at both sides of low post area for center, power forward, and point guard were "pivoting", "screening", and "catching the ball", respectively. The favorite offensive strategies of small forward and shooting guard were "catching the ball" and "getting open" at the right block, and their choices were simply switched at the other block. At the top of the key, the number-one offensive choice for center, power forward, small forward, shooting guard and point guard were "setting screen", "pivoting", "getting open", "getting open", and "catching the ball", respectively. As seen through the results of the study players make their choices and adapt preferences in relation to the positions that they play. Apparently, this is one of the few studies that have tried to differentiate the players according to their playing positions. The subjects' top-three choices on offensive strategies had clearly demonstrated "shooting" was not a top choice at any spot for any role. This clearly indicates that there is need to assess the other factors that affect the choices a player takes in regard to the playing position.

According to results of the study mentioned above, there were significant differences that existed among subjects' choices in term of viewing from a specific role of positions. Since each position usually has been trained to follow a specific role, the results of the study clearly show this phenomenon. Perimeter players such as point guard, shooting guard and small forward would try to receive passes or get open for clear passes at the low-post block. They are usually taught by the coaches to get open in order to score an easy basket under the rim or shoot from outside (Doug *et al.*, 2002) these positions require very good ball handling skills in combination with substantial amounts of agility. Inside players such as center and power forward would demonstrate the fundamental low post move by showing "the pivot" move. They are also taught to set screens at both high- or low-post (Young, 1995; and Wootten, 1992) and these requirements indicate a need for height and explosive strength to pivot and turn. It is probably more appropriate therefore to see those who play at center and power forward positions looking for shots more often (Young, 1995).

2.9.2 Anthropometric and Physiological Studies on Basketball Players

Jeremy *et al.* (2004) studied the effect of a men's collegiate basketball season on selected anthropometric and physiological player indices. This study used basketball players competing in the National Collegiate Athletics Association (NCAA) division one and the anthropometry tests done were height and weight, body composition and aerobic fitness (VO_2 max) using a motorized treadmill. A limitation of this study is that although the tests indicated have a high validity they are not sport specific to the game of basketball and do not simulate the conditions during play on court. The study supported the notion that collegiate basketball players require a high level of aerobic fitness and optimal body composition profiles in order to maximize performance. This study contributes towards the knowledge about how a player's fitness may change during a competitive season by looking into the players profiles through out the season. Information on individual player fitness changes is helpful to the coaching staff and athletic trainers responsible for health and well being of the team throughout the year. The study above also recorded that on average; measured anthropometric and physiologic variables did not change significantly from pre- to post-season. However, on an individual basis, some players showed significant changes in body weight, fatness, and aerobic fitness but although some players showed some significant changes there was no clear classification on the positions they played and whether the positional roles were a result of the changes (Jeremy *et al.*, 2004).

Hoffman *et al.* (1999) examined the effect of aerobic capacity on performance, fatigue and heart rate recovery following high intensity anaerobic exercise in national level basketball players by using 20 subjects whose age was ranging between 19.0 - 27 years, their weights were 88.4 - 68.0 kg, their heights were between 194.2 ± 6.0 cm, and their aerobic capacity was 50.2 - 63.8 ml/kg/min. The study used a treadmill test to determine maximal oxygen consumption VO_2 max, a Wingate Anaerobic Power Test (WAnT), and a field test of anaerobic power common to basketball players called the line drill. The line drill is a continuous 143-m sprint with several changes of direction with a 2-minute passive rest between each sprint. In the results the study revealed a moderate correlation between VO_2 max and mean power of the WAnT. However, no significant relationship was observed between VO_2 max and the fatigue-index in either the WAnT or line drill. Little or no correlation was observed between VO_2 max and heart rate recovery in the

WAnT and line drill. These results showed little to no relationship between aerobic capacity and recovery indices from high intensity exercise in basketball players.

The main purpose of the investigation mentioned above was to examine the relationship between maximal aerobic capacity and recovery from high-intensity exercise in basketball players. Previous studies have suggested that aerobic capacity in these athletes is not a significant contributor to basketball performance (Ellis *et al.,* 1998), but it may have a more important role in the recovery processes from high-intensity activity, common to the game of basketball. The study therefore examined 2 specific indices of recovery: the rate of fatigue and cardio deceleration from high-intensity exercise. The results of this study did not support a significant relationship between aerobic capacity and recovery from anaerobic exercise in basketball players. The aerobic capacity of the subjects in this study (50.2 - 63.8 ml/kg/min) was within the range of aerobic capacities previously reported in male basketball players (Tavino *et al.,* 1995). The study notes that the results of the anaerobic tests are more difficult to compare and that performance measures in either the line drill or WAnT, specific to basketball players, were not found in the literature. However, the values observed for both peak and mean power are similar to those reported previously in anaerobic athletes (Kraemer and Newton, 1994). The significant correlation observed between VO_2 max and mean power in the WAnT (*r* 5 0.57) was similar to results reported by Lyttle (1994) However, the above relationship was not observed between aerobic capacity and the sprint times during the line drill. Considering that the line drill and WAnT were of similar duration and intensity, it would seem reasonable to assume that the results would have been analogous. However, differences in the mode of exercise (e.g., cycle vs. run) and the type of athlete exercising (e.g., anaerobic vs. aerobic) may have influenced these results. It appears that the predominant energy supply used during a bout of anaerobic exercise may depend on the individual's competition specialty (Grant *et al.,* 1995). Lyttle (1994) has shown a preferential contribution of either oxidative or glycolytic metabolism for the WAnT, depending on whether the subject was a long-distance runner or a sprinter. This preferential utilization may become further heightened when exercise is more closely related to the individual's natural mode of activity. It was thought that aerobic capacity, although not having a direct performance benefit, would contribute to recovery from the high-intensity exercise common to basketball play. However, the findings of this study were unable to support this relationship. Getchel *et al.* (1998), examining recreationally trained males and females, reported an increasing relationship between oxidative metabolism and fatigue during the latter stages of the WAnT. This pattern was seen only in their female subjects, however, and not in their male subjects.

The relationship between aerobic capacity and exercise recovery appears to have certain limitations. Hoffman *et al.* (1996) suggested that there is an important relationship between aerobic fitness and exercise recovery, but this relationship may be limited. In an examination of infantry soldiers performing the line drill, the fatigue index was significantly higher in soldiers who had aerobic fitness levels 1 and 2 standard deviations below the population mean. It appears that once aerobic capacity is at a certain level, any increase above this level does not present any further benefit to exercise recovery. Apparently, if there is a threshold level of aerobic capacity, it appears to be at a level below that measured in the present study. The study mentioned above was unable to find any relationship between heart rate recovery and aerobic capacity. This was similar to results of a study by Hoffman *et al.* (1999), but in contrast to several investigations that have reported a strong relationship between aerobic capacity and heart rate recovery (Howley and Franks, 1992; Macleod *et al.*, 1993). These results may be partly related to the relative homogeneity in the conditioning status of the subjects.

Howley and Franks (1992) have shown a significant difference in heart rate recovery between trained and untrained individuals. In addition, the contrasting results in aerobic capacity and heart rate recovery may be related to the intensity of exercise. The relationship between heart rate recovery and aerobic capacity has been demonstrated primarily after sub-maximal exercise (Hoffman *et al.*, 1996). Thus, differences in exercise aerobic capacity, recovery and intensity may affect the mechanisms that control cardio deceleration (relationship between sympathetic and parasympathetic activity). The relationship between aerobic capacity and heart rate recovery may become more prevalent after greater bouts of high-intensity exercise. The game of basketball, although similar in metabolic demand (high intensity, intermittent exercise), is of much greater duration than the approximate 5.5 - minute duration of the line drill. As the duration of high-intensity exercise increases, a greater demand from oxidative metabolism is experienced (Macleod *et al.*, 1993). Therefore, in a 40-minute basketball game, the role of oxidative metabolism in supplying energy for performance may be increased, possibly increasing the importance of aerobic capacity for exercise recovery.

The demands for rebounding, jumping, shooting, and playing defense require a decent level of strength and power. In order to claim that a basketball player is in great condition, the players should have the endurance to run tirelessly on the court and possess the strength to engage in the physical battles underneath the basket. There is no doubt that strength training plays an important part in building up the power for the specific demands on the court. College basketball has emphasized strength training to a great degree because it increases overall strength, power, lean body mass, and flexibility. The objective of implementing strength training to improve vertical jumping ability and thereby enhancing overall sport-performance appears well founded. This explains why college coaches prefer their players to stay involved in strength training even under the restrictive practice schedule of the NCAA (Fulton, 1992).

Groves and Gayle (1993) in assessing strength training amongst basketball players surveyed the top 100 men's college basketball teams from the poll of USA today. Their results stated that 98% of the top 100 colleges had a pre-season weight-training program. 75% of them had an in-season training program. The number of the colleges that provided off-season and summer programs was 88 and 64 respectively. The ANOVA test also showed that schools having an in-season weight-training program ranked higher than those without such a program. Although this correlation did not indicate that strength training led to a better record, it reflected that 87% of coaches and athletic directors supported the idea of strength training in their teams. Groves and Gayle (1993) proceeded further and examined the physiological changes of eight college players that engaged in a year-round training program. The repeated ANOVA test revealed the following facts: (1)

Players' percent of body fat decreased. (2) Although the body weight did not vary much after one year, the lean body mass significantly increased. (3) The average improvement in the bench press was about 27.5 pounds, but there was no significant difference in vertical jumps. In addition, Fulton (1992) conducted research on the combined effects of strength and plyometrics training. After an 18-week training period, a player improved his vertical jump by 4.5 inches and added 45 pounds to his bench press performance. He also shortened his time by 4% on the I-test (a test of speed and agility).

There are no data to support the theory that strength training is detrimental to a player's shooting. Shoenfelt (1991) tested the effect of an 8-week strength-training program on player's free throw shooting accuracy. Fourteen female collegiate players were divided into two groups that engaged in weight training and aerobic exercise on an alternating-day basis. The results showed that the immediate effect of weight training was no more detrimental or beneficial on the free throw accuracy than aerobic exercise. Kerbs (2000) tested an entire female basketball team on free throw and speed spot shooting accuracy eight hours after a morning lifting routine. The result disclosed that there was no significant difference on the shooting accuracy between the lifting and non-lifting days. Further the above mentioned study indicated that basketball players could engage in a regular lifting program on game day morning without a loss in shooting accuracy. The results of these studies indicate that there are more advantages than disadvantages to strength training among basketball players, even on game day. The conclusion reached is that strength training for basketball players is beneficial to their overall development as athletes. The goal of the strength training programs is to increase the power of the players not just their size.

Duke and BenEliayhu (1992) looked at the influences of plyometric training on power endurance in high school basketball players. In this study twenty male basketball players aged 16 -19 years participated. All subjects performed counter movement jumps (CMJ) and continue jumps (CJ) on a force platform to measure force, velocity, and power production during vertical jumping. The Wingate anaerobic test was performed on a bicycle ergometer, and the blood lactate concentrations were assessed before and at 5, 30 minutes after the test. The peak and mean power of Wingate anaerobic test were significantly improved in the treatment group; however, the percent fatigue was unchanged. In particular, the blood lactate concentration at baseline in post-test in the treatment group was significantly lower than the control group. Furthermore, the treatment group produced significant increases in 1RM half-squat strength, and the jump height, power, velocity during counter movement jump (CMJ) over training period. There were significant differences only on the 1RM half-squat strength in the control group after training. The results mentioned in the study above lend support to the effectiveness of an eight week combination of weight and plyometric training for improving vertical jump and power performances in high school basketball players, but not the power-endurance.

Johnson *et al.* (2003) looked at the effects of practice volume and intensity on performance during a NCAA division II women's basketball season and documented strength improvements through periodized training programmes. This study monitored the practice intensity and volume of a NCAA Division II women's basketball team to determine the effect on team performance. The study compared the changes in strength, power, anaerobic endurance, and agility after a 5 week controlled conditioning programme and an unsupervised in-season strength program in which intensity was not regulated. During a competitive phase, volume should decrease while intensity and specialization increase. Little information is available on how load and intensity affect team performance during the season.

The study presented by Wu (1998), quotes a study done by DHyundai Choonang Hospital, and Korean National University of Physical Education, Seoul, Korea on the effects of off-season weight training on the muscular function of professional basketball players. The study is another indication of basketball studies that have used few players as they engaged 16 male professional basketball players with a mean age; 27.6±7.4 yr, mean height; 190.9±7.3cm, mean weight; 89.0±7.1kg, mean career or experience 13.0±2.4 yr were evaluated before and after 8 weeks of weight training program (free weights, 4 days/weeks, 8 items/each day, 10 reps, 3 sets, and 70-80% of 1RM). The study assessed knee extensor/flexor and trunk extensor/flexor muscular strength (60/sec), power (120/sec), and endurance (180/sec) with an isokinetic dynamometer. The results indicated substantial gains in trunk extension strength (381 Nm to 433 Nm, 38.9%), power (357 Nm to 418 Nm, 45.4%), and endurance (310 Nm to 354 Nm, 32.5%). Trunk flexion power and endurance improved by 22.0% and 32.1%, respectively. Knee flexor strength (8.8%), power (6.6%), and endurance (5.9%) gains were smaller but still significant. The free weight training program for 8 weeks significantly improved core stability and the knee joint strength, power, and endurance of Korean Basketball League (KBL) players. Knee extension/flexion peak torque values attained in this study were similar to the knee peak torques reported by Wilson *et al.* (1993) in Division-I basketball players in Greece. The weight-training program used in this study suggests that 'good morning' and back squat exercises were highly effective in improving the core strength and dynamic stability of Korean Basketball League (KBL) players.

Woolstenhulme, *et al.* (2003) studied whether ballistic stretching increases flexibility and acute vertical jump height when combined with basketball activity by determining the effects of four different warm-up protocols by using forty-three beginning and intermediate basketball students participated who participated in six weeks 2 times per week of basketball activity. Subjects were divided into four groups according to type of warm-up activity: ballistic stretching, static stretching, sprinting, or basketball shooting (control group). Subjects engaged in a 10 minute overall warm-up as follows: 3 minutes of basketball running drills followed by 7 minutes of their experimental warm-up. The warm-up was followed by 20 minutes of basketball play. Flexibility was measured via sit and reach and vertical jump height before at week one and after at week seven the six weeks. The study indicated that Flexibility increased for the ballistic, static, and sprint groups compared to the control group. The ballistic group had the greatest increase 3.3 A± 3.3 cm, followed by the sprint 3.0 A± 2.7 cm, and static 2.2 A± 3.0 cm. Vertical jump height was not different over the six weeks for any of the groups. However, the ballistic group demonstrated an increase in vertical jump after basketball play when compared to the previous measure on the same day 3.4 A± 2.9 cm increase. The study therefore concluded that ballistic stretching had the greatest increase in flexibility, as well an increase in vertical jump height that was not observed in other groups when followed by 20 min of basketball play. Ballistic stretching can be included as a beneficial component of a basketball warm-up for flexibility and acute vertical jump height increase in recreational basketball participants. This study though with good results cannot be used to make important inferences as regards competitive basketball at elite levels since it did not use elite basketball players.

2.9.3 Basketball Studies on Goal Orientation and Success Attributes

Dong (2002) studied the differences and relationships between male and female high school basketballs' goal orientation, perceived motivational climate, perceived ability, and the sources of their sport confidence. The study used 174 male and female basketball players who had played in a Division-I Tournament. Their average ages was 17.09 years old and of importance were following findings of the study:

(1) Male players had recorded higher scores in perceived ego-climate and the "perfection of skills" and "physical performance" factors of sport-confidence than female players did. (2) Based on the results of simple correlation analyses, both male and female players' task orientation, perceived task-climate, and perceived ability were positively related to the eight factors of sport-confidence source, which included perfection of skills, demonstration of ability, physical performance, physiological/psychological preparation, social support, vicarious experience, leadership styles of coaches, and positive

environment. Male players' ego orientation was positively related to demonstration of ability, physical performance, and social support. Their perceived ego-climate was positively related to demonstration of ability, physical performance, physiological/psychological preparation, social support, vicarious experience, leadership styles of coaches, and positive environment. As for female players, their ego-orientation was positively related to demonstration of ability, physical performance, physiological/psychological preparation, social support, vicarious experience, leadership styles of coaches, and positive environment. Female players' ego orientation, male players' perceived ego climate and the eight factors of sport-confidence source were positively related to pre-competition confidence. (3) Based on the results of the stepwise regression analyses, male players' task orientation and perceived ability could effectively predict the pre-competition sport confidence. The results of the study indicated that more confidence could be generated from a task-oriented environment. Players who were task-oriented also had more confidence. Therefore, the researchers suggested that sport coaches should work harder to create a task-oriented practice environment (climate) to enhance players' confidence. The study supports the proposition that skill mastery is a key component in sports performance that warrants a close study as a predictor of performance and also as a requisite in the selection and preparation of players for competitive play hence this study.

Other studies have proposed different factors associated with success amongst basketball players. Newby and Simpson (1994) studied factors associated with success amongst NBA players; a multiple regression analysis revealed that field goal percentage was the best predictor of success. The finding of this study as regards field goal conversion percentage suggests that the attainments of the offense are more important than are the defensive attainments in predicting the success levels of NBA teams. The study notes the lack of other studies investigating success among NBA players and more surprising it notes that no research appears to have examined what factors are directly associated with skill level, which would best predict a team's winning percentage.

2.10 Summary

Past research demonstrates that basketball requires a substantial amount of physical fitness (Latin *et al.*, 1994; Hoffman *et al.*, 1996). Latin *et al.* (1994) studied among other components, agility, vertical jump and aerobic capacity while Hoffman *et al.* (1991) monitored strength, speed and endurance changes during the course of a basketball division one season. Latin *et al.* (1994) as well cites several investigations that have monitored conditioning over a season or described specific characteristics of basketball players such as muscle force production characteristics and pulmonary function and maximal oxygen consumption (VO_2 max).

Although there are a substantial amount of studies quoted, the literature reviewed reveals an indication of individual players being investigated but not in relation to their positional roles or in comparison to other team sports or as regards the specificity of their roles in the teams. For instance, Latin *et al.* (1994) looked at the physical and performance characteristics of NCAA Division 1 male collegiate basketball players with the aim of developing a physical fitness and performance profile of the players, his study used collegiate basketball players.

Most of the studies in the literature do not relate their studies to the development of physical fitness programs; they also do not concern themselves with the role played by the different positions in the game of basketball. However, he current study went a little further for it was concerned with comparing the scores in agility, aerobic capacity and leg explosive power amongst the basketball players in relation to their playing positions.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

This chapter describes the research design, sampling procedure, instrumentation, pilot study, data collection, data analysis and data presentation techniques as used in the study.

3.2 Research Design

An ex-post facto research design was employed. The method was selected since the study was out to establish the scores as they existed amongst the subjects and then relate them to the playing positions rather than establishing the changes over the playing season.

3.3 Variables

The study dealt with the following variables:

a) Agility as measured by the SEMO Agility Test, VO_2 max as measured by the Multi Stage Shuttle Run Test, and leg explosive strength as measured by the Vertical Jump. These were the dependent variables of the study and represented the individual's scores in the mentioned tests.

b) Experience of the players served as the independent variable in the study and represented the career experience in years.

c) Positional roles of the players – forwards, guards and centers. These variables also served as independent variables in the study.

3.4 Location of Study

The study was carried out in the city of Nairobi in the various training locations of the selected teams. The specific locations were Moi Air base training court for Ulinzi basketball team, Nyayo National stadium for Co-operative bank and Storms basketball teams and Kenya Commercial Bank Sports Club for the Kenya Commercial Bank basketball team. The locations were selected based on the teams training venues.

3.5 Target Population

The target population comprised of male basketball players of the Kenya Basketball Federation Premier League 2005. There were 10 men's teams in the 2005 Premier League, whose list is shown on appendix C. Each team had 12 registered male players, which summed up to 120 male players who were involved in the league.

3.6 Sampling Techniques and Sample Size

A stratified random sampling procedure was used in the study. The teams were drawn from the Kenya Basketball Federation (KBF) 2005 Premier League. Four teams were selected randomly and sampled on the basis of having taken part in the Kenya Basketball Federation (KBF) 2004 Premier League season. The names of the teams selected are also shown on appendix C. Twelve players from each team were then chosen to participate in the study, making a total of 48 players, which represented 40% of the total population. This sample was selected on the basis of the availability of the teams and funds available to conduct the research, the selected teams were a representative of the population (Patton, 1990). The twelve players were selected on the basis of being registered by the Kenya Basketball Federation and having represented their respective teams in the Premier League in over 75% of the total games played in 2005 in the first leg of the league.

3.7 Data Collection Instruments

The SEMO agility test was used to measure agility, the vertical jump to measure the explosive leg power and the multistage shuttle run, to assess the aerobic capacity as described appendix E.

3.8 Pilot Study

A pilot study was carried out with the following objectives: One, to assess the administrability of the test in terms of tools and the subjects' ability to follow instructions. The second reason was to refine the data collection procedure. The team used in the pilot study was not among the ones which participated in the actual data collection. Basketball players from Strathmore University were used in the pilot study during the first leg the Premier League 2005 season.

3.8.1 Validity

The validity of the Multi Stage Shuttle Run Test has been reported to be comparable to laboratory tests with as high a reliability coefficient as r=0.95 and p-value 0.01 (Grant *et al.*, 1995). The correlation between the Multi Stage Shuttle Run Test and the direct measure of VO_2 max is good amongst many studies ranging from 0.83 - 0.91 (Mcnaughton *et al.*, 1996).

A validity of .63 was found when the Semo Agility Test was correlated with the AAHPER Shuttle Run Test (Johnson and Nelson, 1991). The vertical jump has a high validity value of up to r=0.78 as reported by Johnson & Nelson (1991). Barry and Robert (2001) also reported a validity of r=0.906 with a p-value < 0.01.

3.8.2 Reliability

The reliability of the Multi Stage Shuttle Run Test in comparison with laboratory VO_2 max tests has been reported at 0.988 p-value 0.0005 (McNaughton *et al.*, 1996) and the reliability of the SEMO agility Test has been reported as 0.42 p-value at < 0.05. The Vertical Jump Test has a high reliability value r=0.93 (Johnson & Nelson, 1991). Barry and Robert (2001) also reported reliability score of 0.993 with a p-value < 0.01 for the Vertical Jump Test.

3.9 Procedure for Data Collection

The process of data collection included acquiring official permit to conduct the study and then seeking permission from the coaches and attaining letters of informed consent from subjects as indicated in appendix A. Preparing equipment and record sheets by the actual dates of testing to enhance the administrability of the SEMO Agility test, the Vertical Jump Test and the Multi Stage shuttle run test then followed. During the tests there was use of verbal and audio instructions on how to progress in the tests. The tests were done once in the second leg of the Kenya Basketball Federation Premier League, 2005.

Warm up exercises and some stretches that started with static and then dynamic stretches were done before the tests were carried out. The researcher gave encouragement to the subjects as way of motivating them to continue in the tests especially the Multi Stage Shuttle Run. The tests were administered during the training sessions and all observations recorded in the protocol sheets (Appendix B). The Vertical Jump was the first test followed by the SEMO Agility test and the Multi Stage Shuttle Run Test in that order.

The data obtained was subjected to statistical analysis using the descriptive statistics; mean, mode and variance. One-way analysis of variance (ANOVA) was used to test the research hypotheses. All statistical analyses were carried out using Statistical Package of Social Sciences (SPSS).

3.10 Test Procedures

The test procedures used in the study are described in appendix F.

3.11 Data Analysis and Presentation

Data collected from this study was subjected to statistical analysis using the Statistical Package for Social Science (SPSS). Descriptive statistics of mean and standard deviation were used in the analysis of data. The One Way Analysis of Variance (ANOVA) was used to test the research hypotheses. The data was then presented using tables.

3.12 Logistical and Ethical Considerations

The researcher acquired official permit to conduct research as indicated in Appendix A. The players who were injured were not allowed to take part in the study. Confidentiality on the part of the players and the teams was also assured and maintained throughout study. The protocol used in the study was approved by Kenyatta University ethical committee through the board of postgraduate studies.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the hypotheses of the study, analysis of data, interpretation and discussion of the results. The demographic descriptions of the sample are described in first place followed by analysis of hypotheses with respective discussions of the results.

4.2 Hypotheses of the Study

HO1 There was no significant difference in agility among the guards, the forwards and the centers in the 2005 Kenya Basketball Federation Premier League.

HO2 There was no significant difference in leg explosive power among guards, forwards and centers in the 2005 Kenya Basketball Federation League.

HO3 There was no significant difference in aerobic capacity amongst guards, forwards and centers in the 2005 Kenya Basketball Federation League.

HO4 There was no significant difference in the age amongst male basketball players in the 2005 KBF premier league.

HO5 There was no significant difference in the playing experience amongst male basketball players in the 2005 KBF premier league

HO6 There was no significant difference in the height amongst male basketball players in the 2005 KBF premier league.

4.3 Demographic Details of the Subjects

In this section, frequency distributions and percentage were used to describe and summarize the data with reference to age, height, experience in the league and positional roles of players in the sampled teams. Thereafter, the sample statistics are presented.

4.4 Age and Height of Subjects

The table below shows players' distribution according to age and height.

Table 4.1 Distribution of Players by Age and Height

AGE (Yrs)	FREQUENCY	%	HEIGHT (Meters)	FREQUENCY	%
21	1	2	1.52	1	2
23	2	4	1.56	4	9
24	4	8	1.77	2	4
25	14	30	1.80	6	13
26	6	13	1.82	5	10
27	6	13	1.85	5	10
28	4	8	1.86	1	2
29	4	8	1.89	8	18
30	1	2	1.92	3	6
32	2	4	1.95	3	6
34	2	4	1.98	5	10
36	1	2	2.04	2	4
37	1	2	2.07	3	6
TOTAL	**48**	**100**	**TOTAL**	**48**	**100**

Table 4.1 above indicates that the age of twenty-five years constituted the highest number of players, namely, 14 in total, representing 30% of the total sample. This was followed by ages 26 and 27, which had 6 players each, representing 13%. The age of 21 represented the youngest players in the sample and had 1 player only representing 2%, while the oldest player aged 37 was also only 1 representing (2%) of the total players. On overall, players aged 25 years and below were 21 (44%), while those aged between 26 to

29 years were 20 (42%). The rest of the players namely, 7 (14%) were above 30 years of age.

The distribution of players by their height is also shown in Table 4.1 above; whereby the height of 1.89m had the highest number of players namely, 8 (18%) of the total sample of players. This was followed by the height of 1.80m recorded by 6 players (13%). The heights of 1.82m, 1.85m, and 1.98m followed and were recorded by 5 players (10%) each. The lowest height in the sample was 1.52m recorded by one player (2%), while the highest was 2.07m recorded by 3 players (6%). The mean height recorded here was 1.82m.

The Mean heights recorded for elite senior female players are 1.89m, 1.81m and 1.72m for the center, forwards and guards, respectively (Stone and Steingard 1993). This indicates the obvious differences between positions. The average team heights for female and male Australian Institute of Sports players in basketball is 1.80m and 1.99m, respectively indicating significant differences not only between team players but also between different genders. Data according to the Australian Sports Commission (1998) indicates a mean height of 1.98m for the centers, 1.89m for the forwards, and 1.74m for the guards during the 1994 senior female basketball world championships. In comparison, the heights for the Kenyan players in this study were recorded at 1.98m for the centers, 1.78m for the forwards and 1.80m for the guards. The values for the Kenyan players above clearly indicate that it is only on the position of the forwards that the data from the Australian sports commission differs with the data obtained from Kenyan basketball players. Kenya forward players recorded a lower mean of 1.78m as compared to their Australian counterparts who had 1.89m. Kenyan players playing the guard position seem slightly taller in average with a mean of 1.80 as compared to the Australians with a mean of 1.74m.

Height certainly appears to be a critical component for potential performance, which is more relevant for the center and forward positions as compared to the guard position which generally requires greater emphasis on ball handling skills including passing and shooting specifically (Miller and Bartlett 1996). The literature reviewed indicates that the shorter and lighter stature of the guards gives them greater speed and agility to fulfill their requirements. The average recorded heights for male basketball players by the Australian Institute of Sports is 1.99m, the recorded mean height for the Kenyan basketball players is 1.82m. In a study conducted by Wu (1998) on Korean Basketball League (KBL) first division recorded a mean height of 1.90 ± 0.73m. In another study by Hoffman *et al.*, (1999) the mean height of the subjects was recorded at 1.94 ± 0.6m. This indicates that the Kenyan basketball players are shorter on average as compared to world-class basketball players and this may partly explain their poor performances since height is a critical factor in the game of basketball.

4.5 Experience of Players

The table below shows players distribution according to experience.

Table 4.2 Distribution of Players by Experience

EXPERIENCE (Yrs)	FREQUENCY	%
1.00	1	2
2.00	4	9
3.00	2	4
4.00	12	25
5.00	8	17
6.00	8	17
7.00	3	6
8.00	3	6
9.00	2	4
10.00	2	4
15.00	3	6
TOTAL	**48**	**100**

Table 4.3 shows that, majority of players in the sample had an experience of four years of playing basketball, which was represented by 25% of the total population. This was followed by 5 and 6 years, which constituted 17% each, and two years of experience, which had 9% of players in the total sample. The least number of years of experience was one year, represented by 2% of the total number of subjects, while the highest number of years of experience was 15 years, constituting 6% of the total sample.

Most of the literature and the studies reviewed by the researcher in this study did not record the playing experience as a factor in the studies. However, some of the studies indicate the age of the players as a basis for their studies. The studies do not also compare the outcome of the results in terms of the age of the experience of the players. In a study conducted by Wu (1998) the age of Korean division one-basketball players was reported as 27.6 ± 7.4 years. This study also records the player career experience of 13.0 ± 2.4 years. Hoffman *et al.* (1999) in their study used players ranging between 19.0 – 27 years.

In comparison to the Kenya basketball players in this study the least experienced player had played competitive basketball for one year while the most experienced had played for fifteen years. The age of players may be used as a factor in predicting the scores of some fitness tests like VO_2 max and hence performance.

4.6 Positional Status of Subjects

Table 4.3 Distribution of the Players by their Positional Status

POSITIONS	FREQUENCY	%
Forwards	17	35
Centers	8	17
Guards	23	48
TOTAL	**48**	**100**

The position of the guards had the highest number of players, namely, 23 which constituted 48% in the total sample. This was followed by the forwards who were 17 which represented 35% of the total sample, while the centers were 8, representing 17%. This distribution shows the typical defensive and offensive nature of basketball, whereby there are many players in the positions of the guards and forwards who work along the perimeter while defending, than in the center position who work from under the basket.

4.7 Statistical Analysis of Hypotheses

This section presents the results of the statistical analyses of the study's hypotheses.

4.7.1 Differences in Agility among the Guards, the Forwards and the Centers in the 2005 Kenya Basketball Federation Premier League

The table below indicates the raw data on the agility scores of the subjects.

Table 4.4 Raw Data on agility scores for teams

SUBJECTS	POSITION	AGILITY (Sec)
A1	Forward	18.23
A2	Guard	18.47
A3	Center	18.13
A4	Forward	18.23
A5	Guard	18.72
A6	Guard	17.15
A7	Center	16.69
A8	Guard	17.31
A9	Forward	17.41
A10	Guard	17.55
A11	Guard	17.65
A12	Guard	17.15
B1	Forward	17.54
B2	Forward	17.09
B3	Guard	17.00
B4	Forward	17.11
B5	Center	17.56
B6	Forward	16.44
B7	Guard	16.22
B8	Center	17.59
B9	Guard	15.38
B10	Forward	16.17
B11	Guard	15.33
B12	Forward	16.41
C1	Center	19.09
C2	Guard	16.08
C3	Guard	16.62
C4	Center	17.56
C5	Guard	17.43

SUBJECTS	POSITION	AGILITY (Sec)
C6	Forward	21.67
C7	Guard	17.82
C8	Forward	17.48
C9	Forward	17.31
C10	Guard	16.67
C11	Guard	16.58
C12	Forward	17.31
D1	Guard	16.46
D2	Guard	19.11
D3	Guard	17.20
D4	Guard	17.28
D5	Guard	16.43
D6	Center	16.51
D7	Guard	16.38
D8	Forward	18.21
D9	Forward	18.00
D10	Center	18.11
D11	Forward	18.02
D12	Forward	16.45

Key:

Teams A = A1 . . .A_n

Teams B = B1 . . .B_n

Teams C = C1 . . .C_n

Teams D = D1 . . .D_n

The first null hypothesis (Ho_1) stated that there was no significant difference in agility among the guards, the forwards and the centers in the 2005 Kenya Basketball Federation Premier League. One way analysis of variance at 0.05 Level of significance was used to test this hypothesis, and the results of the analysis are shown in Table 4.5 below.

Table 4.5 ANOVA for Differences in Agility among the Guards, the Forwards and the Centers in the 2005 Kenya Basketball Federation Premier League

POSITIONS	N	MEAN	F Test	Sum of Squares	df	Mean Square	F	Sig.
Forwards	17	16.52	Between Groups	7.305	2	3.653	.485	.619
Centers	8	17.65	Within Groups	338.900	45	7.531		
Guards	23	17.04	Total	346.206	47			

According to the results in Table 4.5 above, there was no statistical difference in agility among the guards, the forwards and the centers in the 2005 Kenya Basketball Federation Premier League. Hence, the null hypothesis was accepted at $p < 0.05$. In fact, as shown in table 4.5 the means of forwards, centers and guards do not differ markedly. This implied that across all the three positions, the agility showed minimal differences. This could be attributed to the same training drills of muscular development associated with strength training that lead to certain muscle fibers being activated than others, which improves coordination in the players.

The above results concur with the earlier findings that progressive resistance exercises tend to affect favorably the coordination of performers (Johnson and Nelson, 1991). Traditionally, it was generally believed that agility was almost entirely dependent upon one's heritage and other physical factors like height, hence the notion that guards are more agile as they tend to be shorter. However, modern research has revealed that agility could be improved through practice, specific training and instruction that improve coordination (Macleod *et al.*, 1993). In this way, therefore, all the players regardless of their specialized playing positions had the similar agility. The players in the teams that were tested engaged in the same type of drills regardless of the positions played. Although the literature reviewed indicates that the shorter and lighter stature of the guards gives them greater speed and agility to fulfill their requirements as a player, this was not reflected in the results of the Kenyan players.

4.7.2 Differences in Leg Explosive Power among Guards, Forwards and Centers in the 2005 Kenya Basketball Federation League

The table below indicates the raw data on the vertical jump scores of the subjects.

Table 4.6 Raw Data on Vertical Jump scores for Basketball teams

Team A

SUBJECTS	POSITION	V JUMP (Cm)
A1	Forward	63
A2	Guard	57
A3	Center	67
A4	Forward	59
A5	Guard	63
A6	Guard	63
A7	Center	66
A8	Guard	82
A9	Forward	68
A10	Guard	67
A11	Guard	68
A12	Guard	60

Team B

SUBJECTS	POSITION	V JUMP
B1	Forward	67
B2	Forward	68
B3	Guard	70
B4	Forward	73
B5	Center	65
B6	Forward	67
B7	Guard	77
B8	Center	60
B9	Guard	60
B10	Forward	71
B11	Guard	64
B12	Forward	67

Team C

SUBJECTS	POSITION	V JUMP (cm)
C1	Center	59
C2	Guard	72
C3	Guard	66
C4	Center	78
C5	Guard	62
C6	Forward	56
C7	Guard	67
C8	Forward	61
C9	Forward	69
C10	Guard	76
C11	Guard	59
C12	Forward	63

Team D

SUBJECTS	POSITION	V JUMP (Cm)
D1	Guard	82
D2	Guard	61
D3	Guard	69
D4	Guard	76
D5	Guard	51
D6	Center	69
D7	Guard	74
D8	Forward	68
D9	Forward	70
D10	Center	73
D11	Forward	80
D12	Forward	77

4.7.3 Differences in Leg Explosive Power among Guards, Forwards and Centers in the 2005 Kenya Basketball Federation League

The null hypothesis (Ho_2) stated that there was no significant difference in leg explosive power among the guards, the forwards and the centers in the 2005 Kenya Basketball Federation Premier League. One way analysis of variance at 0.05 level of significance was used to test this hypothesis. The results of the analysis are shown in Table 4.7 below.

Table 4.7 ANOVA for Differences in Leg explosive Power among the Guards, the Forwards and the Centers in the 2005 Kenya Basketball Federation Premier League

POSITIONS	N	MEAN		Sum of Squares	df	Mean Square	F	Sig.
Forwards	17	63.76	**Between Groups**	129.132	2	3.653	.441	.646
Centers	8	67.12	**Within Groups**	6583.847	45	7.531		
Guards	23	67.21	Total	6712.979	47			

From the results in Table 4.7 above, there was no statistical difference in leg explosive power among the guards, the forwards and the centers in the 2005 Kenya Basketball Federation Premier League. This can also be seen from the negligible difference in the means of forwards, centers and guards. Thus, the null hypothesis was accepted at $p < 0.05$. This shows that in all the positions, differences in leg explosive power amongst the subjects were negligible. This is still attributed to the same training drills of muscular development that all the players underwent.

Normative data relating to vertical jump performance for elite performers in basketball have been recorded as 71cm (average) in the NCAA division one-basketball players (Young, 1995). In comparison to the Kenyan scores, Kenyan basketball players are still low with an average of 66.03cm of recorded vertical jump height. Vertical jumping, in its many different forms, requires high levels of explosive muscular strength. Basketball players typically jump from one leg to perform a lay up, and from two legs to rebound jump, again both are very different styles of jumping which are fundamentally similar in their movement patterns (Harmen *et al.*, 1990). Different jumping styles also involve very different approaches and run ups, which increase or decrease the velocity of the movement performed, depending on the type of jump. The vertical jump test used here was the broad jump with an arm swing and this may explain the differences in the present results and those of other studies. It has been suggested that different styles of jumping require different strength properties and that training for one type of jumping technique will not necessarily improve performance in another style of jumping. This could be used to explain the lack of difference among the basketball players tested. The results and the studies done previously also imply that to improve performance players must engage in the correct training methods so as to improve the leg explosive strength. Since different jumping styles require different training methods and one method does not guarantee the success of the other, it implies that different playing positions would not only require different training methods and testing methods but also different bouts and period of training specific to their playing positions. The correct testing method would give the correct feedback for the enhancement of performance in the sport.

Previous research has indicated the significance of leg explosive strength in all the basketball players regardless of their positional status. For instance, Hoffman *et al.* (1996) demonstrated the important relationships between leg strength, vertical jump, speed and agility on playing time and performance. They also found that upper body strength and aerobic endurance are important components of a basketball player's preparation. Because basketball requires numerous skills, which must be applied dynamically, explosively and repeatedly, strength of the arms and legs are both important to consider in fitness testing programs (Scheller and Rask, 1993). High repetition jumping, which improves vertical jump, is not a characteristic of training and competition for basketball players in general and the same applies to Kenyan basketball teams. This is quite common amongst the volleyball players who make use of several different jumping techniques during spiking and blocking. This also further explains the low scores for the vertical jump tests obtained. The game of basketball requires the player to carry a ball and often to take off on one foot while executing a lay up. The players also often jump without full use an effective arm swing as compared to a game like volleyball and this further explains the disparity in the results of the vertical jump in different sports.

Basketball players are generally exposed to less jumping in training and competition, compared to volleyball players.

4.7.4 Differences in Aerobic Capacity among Guards, Forwards and Centers in the 2005 Kenya Basketball Federation League

The table below indicates the raw data on the aerobic capacity scores of the subjects.

Table 4.8 Raw Data on Multi Stage Shuttle Run Test for Aerobic Capacity

Team A

SUBJECTS	SHUTTLES	PREDICTED $V_{O2}MAX$
A1	11.4	51.4
A2	12.4	54.8
A3	13.6	59.3
A4	12.8	56.0
A5	11.4	51.4
A6	11.12	53.7
A7	13.6	59.3
A8	21.8	86.5
A9	11.6	51.9
A10	11.2	50.8
A11	11.4	51.4
A12	10.4	48.0

Team B

SUBJECTS	SHUTTLES	PREDICTED $V_{O2}MAX$
B1	13.8	59.8
B2	11.6	51.9
B3	12.4	54.8
B4	12.8	56.0
B5	10.4	48.0
B6	11.4	51.4
B7	10.4	48.0
B8	10.2	47.4
B9	16.4	68.5
B10	13.2	58.2
B11	11.4	51.4
B12	13.4	58.7

Team C

SUBJECTS	SHUTTLES	PREDICTED $V_{O2}MAX$
C1	10.4	48.0
C2	12.6	55.4
C3	11.2	50.8
C4	12.8	56.0
C5	14.2	61.7
C6	11.6	51.9
C7	21.2	85.2
C8	13.8	59.8
C9	10.2	47.4
C10	14.2	61.7
C11	12.4	54.8
C12	12.8	56.0

Team D

SUBJECTS	SHUTTLES	PREDICTED $V_{O2}MAX$
D1	12.4	54.8
D2	10.2	47.4
D3	12.6	55.4
D4	12.8	56.0
D5	12.4	54.8
D6	12.8	56.0
D7	13.2	58.2
D8	11.4	51.4
D9	12.8	56.0
D10	10.4	48.0
D11	11.4	51.4
D12	11.2	50.8

The null hypothesis (Ho_3) indicated that there was no significant difference in aerobic capacity among the guards, the forwards and the centers in the 2005 Kenya Basketball Federation Premier League. This hypothesis was tested using One-way analysis of variance at 0.05 Level of significance as summarized in Table 4.9.

Table 4.9 ANOVA for Differences in Aerobic Capacity among the Guards, the Forwards and the Centers in the 2005 Kenya Basketball Federation Premier League

POSITIONS	N	MEAN		Sum of Squares	df	Mean Square	F	Sig.
Forwards	17	51.09	**Between Groups**	386.789	2	193.395	1.584	.216
Centers	8	52.75	**Within Groups**	5494.819	45	122.107		
Guards	23	57.19	Total	5881.608	47			

The results in Table 4.9 indicate that there was no statistical difference in aerobic capacity amongst the guards, the forwards and the centers in the 2005 Kenya Basketball Federation Premier League. However, although the means of forwards, centers and guards slightly differ from one another the differences were not statistically significant. Therefore, the null hypothesis was accepted ($p<0.05$). This shows that regardless of the position played, differences in aerobic capacity were insignificant amongst all the players. This could perhaps be as a result of the same training drills offered to the players, the 20-meter sprints, the maximal oxygen consumption (VO_2 max) test and the 20-meter Multi Stage Shuttle Run Test (Scheller and Rask, 1993;). Typical VO_2 max scores for elite basketball players are around 45 - 55 ml/kg/min for males, 40 - 50 ml/kg/min, for females. These scores are not very different to those of the soccer players (53 - 67 ml/kg/min), volleyball players (50 - 60 ml/kg/min), and American football players (43 - 55 ml/kg/min) (Bergemann, 1991). The Kenyan basketball players in this test recorded an average score of 53.68 ml/kg/min, which shows a good correlation with world-class players in basketball and other sports as indicated above. The above shown scores may also be explained by the fact that elite basketball players would spend a majority of their time in training and developing the aerobic qualities either through running or ball work such as in ball handling and dribbling drills. Moreover for elite level basketball player's training and competitions are primarily comprised of short duration, high intensity work efforts interspersed with relatively short rest periods. In the game of basketball work periods are usually longer than rest periods and the overall distance covered in a game is high. This is reflected in the type of training these athletes commonly engage in.

Aerobic capacity is an important component for basketball players and continuous periods of effort are required throughout a full-length game and especially within a heavy training session, which must utilize oxygen for performance. Jeremy *et al.* (2004) assert that collegiate basketball players require a high level of aerobic fitness and optimal body composition profiles in order to maximize performance.

Hoffman *et al.* (1999) examined the effect of aerobic capacity on performance, fatigue and heart rate recovery following high intensity anaerobic exercise in national level basketball players and recorded aerobic capacity of 50.2 - 63.8 $ml \cdot kg \cdot min^{-1}$. The study in this investigation used a treadmill test to determine maximal oxygen consumption VO_2 max. The aerobic capacity of the subjects in this study (50.2 - 63.8 ml/kg/min) was within the range of aerobic capacities previously reported in male basketball players (Tavino *et al.*, 1995).

In this study, the guards recorded the highest VO_2 max of 57.19 ml/kg/min and this indicates the slight difference in terms of the position played. Interestingly the forwards scored lower than the centers, namely, 51.09 ml/kg/min against 52.75 ml/kg/min respectively yet forwards are seen to be less active on the court. The differences in the VO_2 max scores may be as a result of the different positions played. However, Hoffman *et al.* (1999) argues that differences in the mode of exercise such as cycle vs. run and the type of athlete exercising such as anaerobic vs. aerobic may influence these results and hence the differences in various VO_2 max tests quoted in the literature.

4.7.5 Differences in Age among Guards, Forwards and Centers in the 2005 Kenya Basketball Federation League

The table below indicates the raw data on the age scores of the subjects.

Table 4.10 Raw Data on Age amongst the teams

Team A

NAMES	POSITION	AGE (Yrs)
A1	Forward	25
A2	Guard	34
A3	Center	27
A4	Forward	32
A5	Guard	26
A6	Guard	28
A7	Center	25
A8	Guard	25
A9	Forward	27
A10	Guard	25
A11	Guard	25
A12	Guard	25

Team B

NAMES	POSITION	AGE (yrs)
B1	Forward	25
B2	Forward	37
B3	Guard	25
B4	Forward	25
B5	Center	27
B6	Forward	27
B7	Guard	29
B8	Center	28
B9	Guard	25
B10	Forward	24
B11	Guard	28
B12	Forward	25

Team C

NAMES	POSITION	AGE(yrs)
C1	Center	32
C2	Guard	24
C3	Guard	26
C4	Center	23
C5	Guard	21
C6	Forward	26
C7	Guard	26
C8	Forward	24
C9	Forward	29
C10	Guard	24
C11	Guard	23
C12	Forward	25

Team D

NAMES	POSITION	AGE(yrs)
D1	Guard	27
D2	Guard	36
D3	Guard	30
D4	Guard	34
D5	Guard	25
D6	Center	26
D7	Guard	25
D8	Forward	29
D9	Forward	28
D10	Center	27
D11	Forward	26
D12	Forward	29

The null hypothesis (Ho_4) stated that there was no significant difference in age among the guards, the forwards and the centers in the 2005 Kenya Basketball Federation Premier League. One way analysis of variance at 0.05 Level of significance was used and the results are summarized in Table 4.11.

Table 4.11 One Way Analysis of Variance for Differences in Age among the Guards, the Forwards and the Centers in the 2005 Kenya Basketball Federation Premier League

POSITIONS	N	MEAN		Sum of Squares	df	Mean Square	F	Sig.
Forwards	17	27.23	**Between Groups**	2.070	2	1.035	.089	.915
Centers	8	26.87	**Within Groups**	521.847	45	11.597		
Guards	23	26.78	**Total**	523.917	47			

The results in Table 4.11 show that there was no statistical difference in age among the guards, the forwards and the centers in the 2005 Kenya Basketball Federation Premier League. This can also be directly inferred from the negligible differences in the mean of ages of forwards, centers and guards. The null hypothesis was accepted ($p < 0.05$). This implies that age was not an important factor as far as the performances in the specific positions was concerned. This could be attributed to the fact that the skills and drills in basketball can easily be grasped across differing age groups. Basketball is also a game that is highly specific on mastery of the skills of dribbling and shooting and a player would therefore still be useful on the court despite their age as long as they can shoot well or dribble the ball well. Age therefore did not seem to affect performance.

4.7.6 Differences in Experience among Guards, Forwards and Centers in the 2005 Kenya Basketball Federation League

The table below indicates the raw data on the experience scores of the subjects.

Table 4.12 Raw Data on Experience amongst the teams

Team A

NAMES	POSITION	EXPERIENCE(yrs)
A1	Forward	4
A2	Guard	15
A3	Center	4
A4	Forward	10
A5	Guard	4
A6	Guard	6
A7	Center	4
A8	Guard	4
A9	Forward	5
A10	Guard	3
A11	Guard	4
A12	Guard	5

Team B

NAMES	POSITION	EXPERIENCE (yrs)
B1	Forward	4
B2	Forward	15
B3	Guard	6
B4	Forward	4
B5	Center	6
B6	Forward	6
B7	Guard	8
B8	Center	5
B9	Guard	5
B10	Forward	7
B11	Guard	7
B12	Forward	6

Team C

NAMES	POSITION	EXPERIENCE (yrs)
C1	Center	10
C2	Guard	4
C3	Guard	6
C4	Center	2
C5	Guard	3
C6	Forward	2
C7	Guard	4
C8	Forward	4
C9	Forward	9
C10	Guard	5
C11	Guard	2
C12	Forward	5

Team D

NAMES	POSITION	EXPERIENCE (Yrs)
D1	Guard	8
D2	Guard	15
D3	Guard	8
D4	Guard	9
D5	Guard	2
D6	Center	4
D7	Guard	4
D8	Forward	6
D9	Forward	6
D10	Center	5
D11	Forward	5
D12	Forward	7

The null hypothesis (Ho_5) stated that there was no significant difference in experience among the guards, the forwards and the centers in the 2005 Kenya Basketball Federation Premier League. One way analysis of variance at 0.05 level of significance was used. The analyses are summarized in Table 4.13 below.

Table 4.13 One-Way Analysis of Variance for Differences in Experience among the Guards, the Forwards and the Centers in the 2005 Kenya Basketball Federation Premier League

POSITIONS	N	MEAN		Sum of Square	df	Mean Square	F	Sig.
Forwards	17	5.94	**Between Groups**	6.019	2	3.009	.286	.753
Centers	8	5.00	**Within Groups**	473.898	45	10.531		
Guards	23	5.95	**4.7**	479.917	47			

Table 4.13 shows that there was no significant difference in years of experience among the guards, the forwards and the centers in the 2005 Kenya Basketball Federation Premier League. Indeed, there is a negligible difference in the means of forwards, centers and guards as shown in Table 4.13 above. Therefore, the null hypothesis was accepted ($p < 0.05$). The results imply that experience, just like age, was not an important factor as far as performance in specific positions was concerned. The same argument used for age could be applied here, that the skills and drills in basketball can easily be grasped across differing age groups. Experience did not seem to be a factor in the three tests that were carried out and whether or not the more experienced players had mastered the skills applicable to the game of basketball, was not directly reflected since the differences were negligible.

4.7.7 Differences in Height among Guards, Forwards and Centers in the 2005 Kenya Basketball Federation League

The table below indicates the raw data on the height scores of the subjects.

Table 4.14 Raw Data on Height amongst the teams

Team A

SUBJECTS	POSITION	HEIGHT (Mts)
A1	Forward	1.89
A2	Guard	1.95
A3	Center	1.86
A4	Forward	1.95
A5	Guard	1.89
A6	Guard	1.89
A7	Center	2.07
A8	Guard	1.89
A9	Forward	1.98
A10	Guard	1.56
A11	Guard	1.86
A12	Guard	1.86

Team B

SUBJECTS	POSITION	HEIGHT (Mts)
B1	Forward	1.98
B2	Forward	1.98
B3	Guard	1.56
B4	Forward	1.8
B5	Center	2.04
B6	Forward	1.89
B7	Guard	1.8
B8	Center	2.04
B9	Guard	1.89
B10	Forward	2.07
B11	Guard	1.83
B12	Forward	1.86

Team C

SUBJECTS	POSITION	HEIGHT (Mts)
C1	Center	2.07
C2	Guard	1.95
C3	Guard	1.86
C4	Center	1.98
C5	Guard	1.92
C6	Forward	1.8
C7	Guard	1.77
C8	Forward	1.83
C9	Forward	1.98
C10	Guard	1.56
C11	Guard	1.83
C12	Forward	1.92

Team D

SUBJECTS	POSITION	HEIGHT (Mts)
D1	Guard	1.83
D2	Guard	1.8
D3	Guard	1.83
D4	Guard	1.89
D5	Guard	1.56
D6	Center	1.89
D7	Guard	1.8
D8	Forward	1.86
D9	Forward	1.89
D10	Center	1.92
D11	Forward	1.8
D12	Forward	1.77

The null hypothesis (Ho_6) specified that there was no significant difference in height among the guards, the forwards and the centers in the 2005 Kenya Basketball Federation Premier League. One-way analysis of variance at 0.05 Level of significance was used to test the hypothesis as summarized in Table 4.15 below.

Table 4.15 One-Way Analysis of Variance for Differences in Height among the Guards, the Forwards and the Centers in the 2005 Kenya Basketball Federation Premier League

POSITIONS	N	MEAN		Sum of Squares	df	Mean Square	F	Sig.
Forwards	17	1.78	Between Groups	2.570	2	1.285	1.376	.263
Centers	8	1.98	Within Groups	42.020	45	.934		
Guards	23	1.80	4.7	44.590	47			

From Table 4.15 it is evident that there was no significant difference in height among the guards, the forwards and the centers in the 2005 Kenya Basketball Federation Premier League. The means of forwards, centers and guards as shown in Table 4.15 do not differ considerably. Hence, the null hypothesis was accepted ($p < 0.05$). The results imply that height also was not a major factor in the positional performance of players. Indeed, unique types of body size and proportion may constitute important prerequisites for successful participation in particular sports. Young (1995) stated that although an ideal physique may not be ideal in itself for excellence in a sport, its lack even in the presence of compensating attributes might be a severe handicap to a potential athlete.

The mean heights that were recorded by the three positions do not differ considerably from world-class basketball players. The data collected from the Kenyan basketball players differ slightly when compared to those provided by the Australian Sports Commission (1998) that indicates a mean height of 1.98m for the centers, 1.89m for the forwards, and 1.74m for the guards during the 1994 women's basketball world championships. In comparison to the mean for the Kenyan players which were recorded as 1.98m, 1.78m and 1.80m for Centers, forwards and for the guards, respectively the Kenyans seem to be comparing well with ladies but short as compared to men in elite basketball. The scores above clearly indicate that it is only on the position of the forwards that the data from the Australian sports commission differs with the data obtained from Kenyan basketball players. The Kenyan forward players in the national basketball league have a lower mean of 1.78m as compared to their Australian counterparts who scored 1.89m. The Kenyan players playing the guard position seem slightly taller with a mean of 1.80 as compared to the Australians with a mean of 1.74m. Positional differences require different heights though Kenyan basketball players seem to generally compare well with these world-class basketball players in terms of height.

Previous research has of course indicated the development of the trend towards an increase in height and the variation in heights for positional play in basketball (Carter, 1984): The shorter the player, the higher he has to jump in order to play successfully in the aerial zone. Indeed, if the player were too short, he might then not be physically able to reach the necessary heights despite a good vertical jumping ability (Jeremy et *al.*, 2002). In fact, Wootten (1992) emphasize that elite basketball players are even taller than the volleyball players, especially the centers and forwards; and this physical attribute is particularly important when it is realized that the game involves physical contacts with the intentions of getting the ball in a "basket" elevated 10 feet (3.05 meters) above the floor.

Wu (1998) further asserts that certainly in professional basketball, centers and forwards are unlikely to be selected unless they are in excess of 2 meters in height. This height seems slightly higher as compared to the mean height recorded for the Kenyan basketball players, who had a mean height of 1.98m. He goes ahead to argue that tallness and good jumping ability would be essential prerequisites for participation at elite levels. Although the nature of the game calls for height as indicated in the above related research literature, it is interesting to note that in the present study, the height of the players in specific positions was not a much significant factor to performance as indicated by the heights of the players in the three positions. This partly explains the poor performances of Kenyan teams and the national team as well in continental and regional competitions. The Mean heights recorded for elite senior female players are 1.89m, 1.81m and 1.72m for the center, forwards and guards respectively (Stone and Steingard 1993). This indicates the obvious differences between positions. The average team heights for female and male basketball players of the Australian Institute of Sports is 1.80m and 1.99m, respectively indicating significant differences not only between team players but also between different genders. Data according to the Australian Sports Commission (1998) indicate that a mean height of 1.98m for the centers, 1.89m for the forwards, and 1.74m for the guards was recorded during the 1994 senior female basketball world championships. The tallest Kenyan players who were the centers recorded a height of 2.07m, which seems to compare well with the Australian players. The guards had the shortest height with a mean of 1.52m which is clearly below the average as compared to world-class players who are as tall as 1.74m according to the data presented by the Australian Sports Commission (1998).

Height certainly appears to be a critical component of potential performance, which is more relevant for the center and forward positions. The guard position generally requires greater emphasis on ball handling skills including passing and more specifically shooting (Miller and Bartlett 1996). The literature reviewed indicates that the shorter and lighter stature of the guards gives them greater speed and agility to fulfill their requirements while playing.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This study investigated some selected skill related components of physical fitness amongst male basketball players in the Kenya Basketball Federation (KBF) 2005 Premier League season in Kenya. The purpose of this study was to asses the agility, explosive power, and aerobic capacity of the male basketball players who participated in the Kenya Basketball Federation 2005 premier league, in relation to their playing positions. A stratified random sampling procedure was used to select the teams for the study, in which 48 male basketball players were selected. An ex-post facto research design was used. The assessment of the selected skill related fitness components was assessed using the multistage shuttle run test for aerobic fitness, the vertical jump test to measure explosive leg power, and the SEMO agility test to measure agility. Descriptive statistics including means and standard deviations were used to analyze the data. The One-way analysis of variance (ANOVA) was used to test the research hypothesis.

5.2 Summary of the Findings

The study established the following findings:

- The position of the guards constituted the highest frequency of 23 players, which represented 48% of the total sample. The forwards were 17 representing 35% of the total players, while the centers were 8, which represented 17% of the total sample.

- The age of twenty-five constituted the highest number of players, namely 14 which represented 30% in the total sample of players. The age of 21 represented the youngest players in the sample which was one player representing 2%, while the oldest player was of age 37 who was only one player or 2% of the sample.
- On the overall, there were 14 players (42%) of the total sample in this study who aged 25 years and below. Those from age 26 to age 29 were 20 in number or 44% of the total sample, while the remaining 7 players (14%) had their ages above 30 years.
- The height of 1.89m recorded the highest percent (18%) in total. The lowest height in the sample was 1.52m (2%), while the tallest was 2.07m (6%).
- Majority of players in the sample namely, 25% had an experience of four years of playing basketball in the Premier League. The least number of years of experience was one, represented by 2% of players, while the highest number of years of experience was 15 years, constituting 6% of the total sample.
- There was no statistical difference in agility among the guards, the forwards and the centers in the 2005 Kenya Basketball Federation Premier League.
- There was no statistical difference in leg explosive power among the guards, the forwards and the centers in the 2005 Kenya Basketball Federation Premier League.

- There was no statistical difference in aerobic capacity among the guards, the forwards and the centers in the 2005 Kenya Basketball Federation Premier League.
- There was no statistical difference in age among the guards, the forwards and the centers in the 2005 Kenya Basketball Federation Premier League.
- There was no statistical difference in experience among the guards, the forwards and the centers in the 2005 Kenya Basketball Federation Premier League.
- There was no statistical difference in height among the guards, the forwards and the centers in the 2005 Kenya Basketball Federation Premier League.

5.3 Implications and Findings

Based on the above findings of this study although the guards showed a slightly higher score in the aerobic capacity scores as compared to the centers and forwards, there was no statistical difference among the three groups of players. This indicates that aerobic capacity was not an indicator in the differences on the players in terms of the positions that they were playing and also the demands of play in the different positions. Another interesting finding was that there was no statistical difference amongst the guards, forwards and the centers. Although centers are known to be taller in the game of basketball due to their pivotal role, the Kenyan basketball players did not reflect this attribute and this explains the common characteristic of the players changing positions during the game. The switching of positions in the highly technical game of basketball leads to lack of specialization and the mastery of the needs of the required position and may lead to diminished performance bearing in mind that basketball is highly technical and every position has specific requirements in terms of the skill needed during offensive and defensive play.

The above results also indicate that the position of the guards was the most favored and it constituted 48% of the total sample. The position of the center was represented by a meager 17% of the total sample. This may be used to partly explain the low scores in the Kenya Basketball Federation Premier League and the more defensive structure of the Kenyan teams. Centers work around the post area and are therefore very vital in the scoring of baskets.

5.4 Conclusions

On the overall, the statistical test of the null hypotheses formulated in the study indicated that:

- No statistical significance difference in the variables agility, leg explosive power, aerobic capacity, age, experience, and height among the guards, the forwards and the centers in the 2005 Kenya Basketball Federation Premier League, in the teams investigated under this study.
- The general implication of these findings is therefore that, regardless of the players' positional status in terms of the guards, the forwards and the centers, there are no significant differences with regard to their agility, leg explosive power, aerobic capacity, age, experience and height.
- The most outstanding reason for lack of this significant difference especially in the case of agility, leg explosive power and aerobic capacity is because of

relatively same training drills that the players undergo which tune them to more or less same abilities.

- Due to the same training drills hence, there is the likelihood that the players can as well interchange their positions and adequately execute their skills in the varied positions that they may assume.

5.5 Recommendations

The following recommendations were made based on the findings and conclusions of the study.

5.5.1 Policy and Training

- The Kenya Basketball Federation and clubs should initiate programmes that ensure physical fitness testing during off-season and in season for various components. This will help to establish norms for the game in Kenya. Perhaps this may bring about the expected positional differences due to the requirements of the particular positional role.
- Basketball coaches should develop and adopt training programmes that are specific to different positions in order to embrace the expected differential demands of each positional role in a game of basketball. This could be done through education of the coaches through Kenya Basketball Federation and coaches' commission through coaching courses.

- The Kenya Basketball Federation in conjunction with Schools and Colleges Sports Associations should ensure that the game of basketball is introduced widely throughout the country in schools so as to expose students to the game at an early age and therefore broaden the player base from which players may be selected for both national and international competitions. Through this, the coaches can be able to impart the correct training on the youth as regards the specific requirements of the various positions of play.
- The Kenya Basketball Federation should organize and sponsor regular consultative seminars in order to exchange relevant scientific knowledge and ideas to improve and raise the standards of the game in the country.
- Kenya Basketball Federation should make it mandatory for the basketball clubs to keep updated physiological records of the players throughout the league season so as establish differences and act as a guide to evaluating whether training programmes used are suitable and make relevant changes accordingly. These data would also be useful to screen players for match fitness.

5.6 Further Research

- Further research should be carried out on young players in schools and colleges in order to develop their physiological profiles. Hence, there will be physiological records for basketball players of all categories that will aid in developing suitable training programmes for players at different levels of competitions.

- The aerobic capacity levels of basketball players should be investigated in other major competitions so as to establish whether endurance capacity levels of basketball players would vary with the type of competition and training.

REFERENCES

Australian Sports Commission (1998) Report on Australian basketball. **Australian Journal of Science and Medicine in Sport** 19: 13-17

Adams, K., O'Shea, J.P., O'Shea, K.L., Climstein, M. (1992) The effect of six weeks of squat, plyometric and squat-plyometric training on power production. **Journal of Applied Sport Science Research**. 6. (1) 36-41.

Arnheim, D. D and Prentice, E. W. (2002). **Essentials of Athletic Training.** New York: Mc Graw Hill.

Barry, A. Stockbrugger and Robert G. Haennel. (2001) Validity and Reliability of a Medicine Ball Explosive Power Test. **The Journal of Strength and Conditioning Research.** 15 (4) 431–438.

Bergemann, B. (1999), Analysis of Selected Physical and Performance Attributes of the United States Olympic Team Handball Players: Preliminary Study, **The Sport Journal.** 2 (2) 27 – 41.

Black, W. & Roundy, E. (1994) Comparisons of size, strength, speed and power in NCAA Division 1 Football players. **Journal of strength and conditioning research.** 8 (2) 80-85.

Bobbert, M. F. &Van Soest, A.J. (1994) Effects of muscle strengthening on vertical jump height: a simulation study. **Medicine and science in sports and exercise.** 26 (8) 1012-1020.

Dong, F. (2002) Differences and Relationships between Male and Female High School Basketballs' Goal Orientation, Perceived Motivational Climate, Perceived Ability, and the Sources of Sport Confidence. **Medicine & Science in Sports & Exercise.** 34 (5) Supplement 1 May 2002 p S230

Doug J., James L., Maureen L., Amy S., and Tina P. (2002) Effects of Practice Volume and Intensity on Performance During a NCAA Division II Women's Basketball Season. **Medicine & Science in Sports & Exercise: 34(5) Supplement 1 May,** p 35.

Duke, S. & BenEliayhu D. (1992) Plyometrics: Optimizing athletic performance through the development of power as assessed by vertical leap ability: an observational study. **Chiropractic Sports Medicine.** 6 (1) 10-15.

Ellis L., Gastin P., Lawrence S., Savage B., and Sheales A. (1998) **Testing protocols for the physiological assessment of team sport players.** In Gore J (Ed): Test Methods Manual (3rd Ed). Canberra: Australian Sports Commission.

Fulton, K. T, (1992) Off - season training strength training for basketball. **Journal of Strength and Conditioning.** (14) 1, 31 - 44

Getchell, B, Mikesky, E and Mikesly, N. (1998) **Physical Fitness, A way of Life**. Boston: Allyn and Bacon.

Grant S, Corbett K, Amjad AM, Wilson J and Aitcheson T (1995) A comparison of methods of predicting maximum oxygen uptake. **British Journal of Sports Medicine.** (29)147-152.

Groves, B. R, and R. C. Gayle. (1993) Physiological changes in male basketball players in year round strength training. **Journal of Strength and Conditioning Research** (7) 1, 30 -33

Harmen, E.A. (1991) Estimation of Human Power output from vertical jump**. Journal of Applied Sports Science Research.** 5 (3), 116-120.

Hoffman J. R., Ishmuel E, Merav E and Yitzhak W, (1999) Effect of aerobic capacity on performance, fatigue and heart rate recovery following high intensity anaerobic exercise in national level basketball players. **Journal of Strength and Conditioning Research**. 13 (4), 407–411.

Hoffman, J. R., C. M. Maresh and L. E. Armstrong. (1992) Isokinetic and dynamic constant resistance strength training: Implications for sport. **Journal of Physiotherapy.** 2 (1), 42-53.

Hoffman, J. R., Fry, A.C., Howard, R., Maresh, C. M. and W. J. Kraemer. (1991) Strength, speed and endurance changes during the course of a division 1-basketball season. **Journal of Applied Sport Science and Research** 5 (3) 144- 149.

Hoffman, J. R., G. Tenenbaum, C. M. Maresh, and W.J. Kraemer. (1996) Relationship between athletic performance tests and playing time in elite college basketball players. **Journal of Strength and Conditioning Research.** 10(2): 67-77.

Howley, T and Franks, D. B. (1992). **Health Fitness: Instructors Handbook**. Champaign: Human Kinetics.

Isaacs L. D. (1998) Comparison of the Vertec and Just Jump system for measuring height of vertical jump for young children. **Perceptual and Motor Skills** (86) 659-663.

Jeremy, K, Ode, J and Fascm, J. M. (2004). Effect of a collegiate basketball season on Anthropometric and Physiological variables. **Medicine & Science in Sports & Exercise.** 36 (5), 32 – 42.

Johnson, Doug; Lynch, James; Lamping, Maureen; Siegal, Amy; Poliska, Tina . (2003) Effects of practice volume and intensity on performance during a NCAA division II women's basketball season. **Medicine & Science in Sports & Exercise: 35 (5) Supplement 1 May 2003** p S371

Johnson, L. B. and Nelson, K. J. (1991). **Practical Measurements for Evaluation in Physical Education. (5th ed.).** Minnesota: Burgess Publishing Company Minnesota.

Kerbs, B. (2000). **Effects of same-day strength training on shooting skills of female collegiate basketball players.**, Oregon: University of Oregon, Microfilm Publication, Eugene.

Kraemer, W. J & Newton, R. U (1994) Training for Improved Vertical Jump. **Gatorade Sports Science Institute,** 7 (6), 1 – 10.

Latin, R. W. K. Berg, and T. Baechle (1994) Physical and Performance Characteristics of NCAA Division 1 Male Basketball Players. **Journal of Strength and Conditioning Research,** 8(4), 214 – 218.

Lyttle, A. (1994) Maximizing power development - a summary of training methods. **Strength and Conditioning Coach. A.S.C.A.** 2 (3), 16-19.

Macleod, D., Maughan, R. J., Williams, C., Madeley, C. R., Sharp J. C. M., Nutton, R. W., (1993). **Intermittent High Intensity Exercise**. London: E& FN Spon

McArdle. W. D., Katch. F. I., and Katch. V. L. (1996) **Exercise Physiology: Energy Nutrition and Human Performance**. (3rd ed.) London: Lea and Febiger.

McInnes. S. E., Carlson J. S., Jones. C. J., and McKenna MJ. (1995) Physiological load imposed on basketball players during competition. **Journal of Sports Sciences** (13) 387-397.

McNaughton. L. Cooley. D., Kearney V., and Smith S. (1996) A comparison of two different shuttle run tests for the estimation of VO_2 max. **Journal of Sports Medicine and Physical Fitness** 36:85 - 89.

Miller. H. D., and Bartlet. R. M., (2002) Use of performance indicators in performance analysis. **Journal of Sports Sciences** 20 (10), 739 – 754.

Nachmias, F. C. and Nachmias D. (2002), **Research Methods in the Social Sciences.** London: St Martin's Press, Inc.

Newby, R. W., and Simpson, S. (1994). Basketball performance as a function of scores on the profile of mood states. **Perceptual and Motor Skills.** (78), 1142.

Patton, M. Q. (1990) **Qualitative Evaluation and Research Methods.** Park London, New Delhi: Sage Publications.

Rosandich, P. T. (1999), International Physical Fitness Test, **The Sport Journal.** (2), 1.

Reilly, T, Secher, N, Snell, P. and Williams (ed) (1990). **Physiology of Sport.** London: Chapman and Hall.

Scheller, A and Rask B (1993) A protocol for health and fitness assessment of Nba players. **Clinics in Sports Medicine** 12:193-206

Shoenfelt, E.L. (1991). Immediate effect of weight training as compared to aerobic exercise on free throw shooting in collegiate basketball players. **Perceptual and motor skills.** 73(2), 367-370.

Smith, H. K. and Thomas S. (1991), Physiological characteristics of elite female basketball players. **Canadian Journal of Sports Science** 16:289-295.

Stapff, A. (1998) **Basketball Players.** In Gore J (Ed): Test Methods Manual (3rd Ed). Canberra: Australian Sports Commission.

Stone, W. J. and Steinguard P. (1993) Year-round conditioning for basketball. **Clinics in Sports Medicine** 12:173-191.

Tavino, L. P., C. J. Bowers, and C. B. Archer. (1995) Effects of basketball on aerobic capacity, anaerobic capacity and body composition of male college players. **Journal of Strength and Conditioning Research** (9)2:75 – 77.

Wilkes, R. (1995) Limitations in Applied Strength Training Research : Current Dilemmas and Recommendations for future studies. **Strength and Conditioning Coach. A.S.C.A. vol. 3. no. 2.** pp.17-20

Wilson, G and Murphy A (1995). The efficacy of isokinetic, isometric and vertical jump tests in exercise science. **Australian Journal of Science and Medicine in Sport 27:20-24.**

Wilson, G. J., Newton, R.U., Murphy, A.J., & Humphries, B.J. (1993) The optimal training load for the development of dynamic athletic performance. **Medicine and Science in Sports and Exercise. 25(11). pp.** 1279- 1286.

Wissel, H. (1994). **Basketball: Steps to Success**. Champaign: Human Kinetics Publishers Inc.

Woolstenhulme, Mandy; Multer, Christine E.; Woolstenhulme, Emily; Parcell, Allen C. (2003) Ballistic Stretching Increases Flexibility and Acute Vertical Jump Height When Combined with Basketball Activity. **Medicine & Science in Sports & Exercise: Volume 35(5) Supplement 1 May 2003** p S381

Wootten, M (1992). **Coaching Basketball Successfully**. Champaign: Leisure Press.

Wu, B.Y. (1998). Developing a forward player, **Journal of Tungnan College,** 21, 219 – 224.

Young, W. (1995) Specificity of Jumping ability. **The Sports Coach. Winter 1995.** pp.22-25

Young WB, MacDonald C, Heggen T and Fitzpatrick J (1997) An evaluation of the specificity, validity and reliability of jumping tests. **Journal of Sports Medicine and Physical Fitness 37:240-245.**

APPENDIX A: LETTER OF REQUEST FOR DATA COLLECTION

Isaac Mwangi Kamande
Strathmore University
P. O. Box 59857,
Nairobi.

Date

The Coach
Stormers Basketball Club
P. O. Box
Nairobi.

Dear Sir,

RE: REQUEST FOR DATA COLLECTION
Iam a graduate student pursuing a Masters of Science degree in the Department of Exercise, Recreation and Sport Science at Kenyatta University.

My aim is to assess selected performance related components of physical fitness amongst the male basketball players in the KBF Premier League 2005. The components to be tested will be agility, explosive power and aerobic capacity. Stormers, Ulinzi, Cooperative bank and Kenya Commercial Bank will be my sample teams. I hope to carry out the tests during the first leg of the Premier League 2005 and then perform a retest in the second leg of the league.

The tests will only be focused on assessing the agility, explosive power and VO_2 max as indicators of the selected performance related components of physical fitness.

It is my wish and promise that these tests will not endanger any of the players. I will make available a copy of my thesis to your team once the research is complete.
It is my sincere wish that you would allow me to carry out my study with your teams.

Thank You.

Yours sincerely,

Isaac Mwangi Kamande

APPENDIX B: EVALUATION PROTOCOL SHEET

NAME: ____

AGE: ____

TEAM ____

PLAYING EXPERIENCE: ________________________

HEIGHT: ______________________________________

POSITIONAL ROLE: ____________________________

HEART RATE: __________________________________

AGILITY TEST SCORE: a) ________ (min) b) _____ (min)

VERTICAL JUMP TEST SCORE: a) _____ (cm) b) ______ (cm)

Test in the 2nd Leg	Level	Shuttle	Predicted VO_2 Max

APPENDIX C: LIST OF TEAMS TAKING PART IN THE 2005 KENYA BASKETBALL FEDERATION (KBF) PREMIER LEAGUE

1. Ulinzi
2. Nakuru
3. Stormers
4. USIU
5. Cooperative bank
6. Telecom
7. Post bank
8. University of Nairobi
9. Kenya Commercial Bank
10. Coast youth

APPENDIX D: LIST OF TEAMS RANDOMLY SELECTED FOR THE STUDY

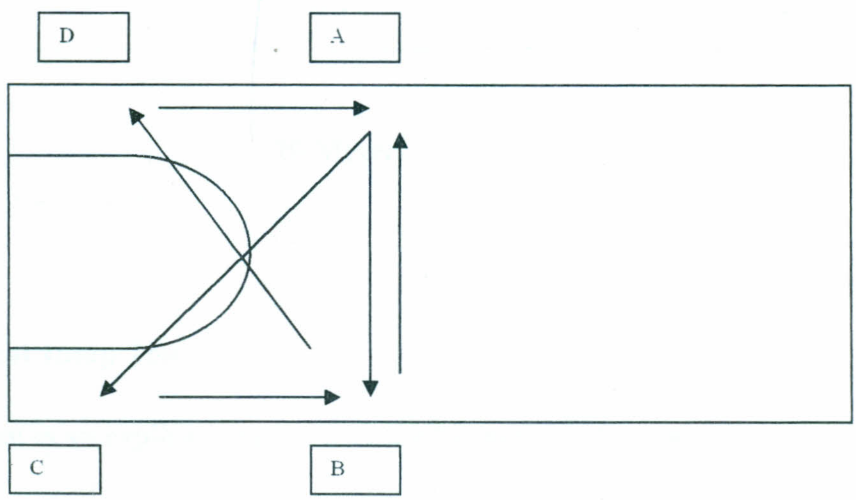
1. Ulinzi
2. Stormers
3. Cooperative bank
4. Kenya Commercial Bank

APPENDIX E: DATA COLLECTION INSTRUMENTS USED IN THE STUDY

SEMO Agility Test

This test is adopted from Johnson and Nelson (1991) and was designed to utilize the free throw lane of a basketball court. Four plastic cones or suitable substitute objects are placed squarely in each corner of the free throw lane. A validity of .63 was found when the SEMO Agility Test was correlated with the AAHPER Shuttle Run Test (Johnson and Nelson, 1991). A stopwatch and the cones are the equipment needed.

Figure 1: Diagram Showing the Set Up For SEMO Agility Test

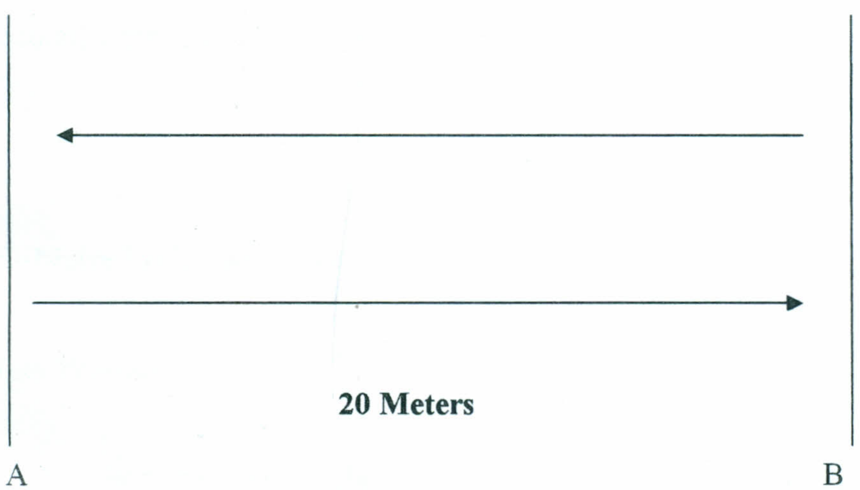


20-Metre Multistage Shuttle Run (MSR)

The shuttle run test estimates the aerobic power of the athlete or the maximum rate at which oxygen can be consumed. It is a commonly used measure of cardio-respiratory fitness in basketball players.

A tape recorder, "Beep" tape, Tape measure, Markers, Basketball court, Protocol sheets as shown in appendix B.

Figure 2: Diagram Showing the Set Up For Multi Stage Shuttle Run



Vertical Jump Test

The test is an explosive motor task used commonly throughout the game of basketball in many different forms (Stone and Steingard, 1993). The test is used as a measure of explosive strength of the legs. This test was chosen because of its high validity, r=0.78 and reliability r=0.93, (Johnson & Nelson, 1991). The "Digital Indication Jump Meter" device was used.

APPENDIX F: TEST PROCEDURES USED IN THE STUDY

SEMO Agility

The subject lined up outside the free throw lane (A). With his back to the free throw line, the subject waited for the signals "ready", "go". The subject side stepped from A to B and passed outside the cone. Then he backpedaled from B to D and passed as to the inside of the corner cone. He then sprinted forward from D to A and passed as outside the corner cone. Then he backpedaled from A to C and passed to the inside of the corner cone. He then sprinted forward from C to B and passed outside of the corner cone. Finally he side stepped from B to the finish line at A. The best of two trials (recorded to the nearest 1/10 second) were recorded as the score (Johnson & Nelson, 1991).

20-Metre Multistage Shuttle Run (MSR)

Test Procedure

1. The test required a flat, even running surface. Preferably the basketball court. The markers used were set clearly with cones 20 meters apart with adequate space at each end that allowed for an appropriate run through or turning as a part of the test. The tape recorder and tape was prepared with the pre recorded timed beeps.
2. Once organized, the players were given a brief period to warm up with some running and stretching.

3. The tape was then started and the players were asked to listen carefully to the instructions provided.
4. The aim was to complete the 20m track in coordination with the "beep" sound from the tape recording. The frequency of the beep was increased every minute. The player needed to place one foot on or over the 20-metre line at the sound of each beep. The test was terminated when the player was no longer able to follow the set pace and did not reach the targeted line on three consecutive occasions.

The score recorded was the level and number of shuttles completed previous to the beep on which the test was terminated. These levels allowed a prediction of VO_2 max to be made.

Vertical Jump Test

Test Procedure

The player stood on the mat with the digital indication meter tied firmly on the waistline and with both hands jumped explosively projecting the body upward. The best of two trials was then be recorded.