AEROBIC CAPACITY AMONG THE RUGBY UNION PLAYERS IN
2005 KENYA CUP LEAGUE

BY

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DECLARATION

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

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DEDICATION

This work is dedicated to my parents, the late Mr. Mathai Karuga and Wambui Mathai, for their commitment and having found it worthwhile to educate their daughter.
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TABLE OF CONTENTS

CONTENTS

DECLARATION ................................................................. i
SUPERVISORS APPROVAL .................................................. ii
DEDICATION .................................................................. ii
ACKNOWLEDGEMENT ....................................................... iii
CONTENT PAGE ............................................................... iv
LIST OF TABLES .............................................................. vii
LIST OF FIGURES ............................................................ viii
LIST OF ABBREVIATIONS .................................................. ix
ABSTRACT .................................................................... x

CHAPTER ONE

INTRODUCTION
1.1 Background to the Study ............................................. 1
1.2 Statement of the Problem ........................................... 4
1.3 Purpose of the Study .................................................. 5
1.4 Objectives of the Study .............................................. 5
1.5 Research Hypotheses ................................................. 6
1.6 Significance of the Study ............................................ 6
1.7 Limitations of the Study ............................................. 7
1.8 Delimitations of the Study ........................................... 8
1.9 Assumptions of the Study .......................................... 8
1.10 Conceptual Framework ............................................. 8
1.11 Operational Definition of Terms ............................... 10

CHAPTER TWO

REVIEW OF RELATED LITERATURE
2.1 Introduction ............................................................... 12
2.2 Maximum Oxygen Uptake ......................................... 12
2.3 Determinants of Aerobic Capacity .............................. 13
2.3 Initial Level of Fitness .............................................. 13
2.3.2 Intensity .............................................................. 13
2.3.3. Duration ............................................................ 14
2.3.4 Frequency ........................................................... 15
2.3.5 Mode of Training/Specificity ................................. 15
2.3.6 Overload ............................................................ 16
2.3.7 Age ................................................................. 17
2.3.8 Gender .............................................................. 18
2.3.9 Individual Differences and Training ..................... 18
2.4 Physiological Adaptations Due to Training .................. 20
2.4.1 Peripheral Adaptations Due to Training ........................................20
2.4.2 Central Fitness ........................................................................24
2.5 Energy Requirements for a Rugby Players .....................................26
2.6 Pulmonary Ventilation and Metabolic Demands ..............................27
2.7 Measurements of Aerobic Capacity ..............................................28
2.7.1 Direct Calorimetry .................................................................29
2.7.2 Motorized Treadmill ...............................................................30
2.7.3 Astrand and Rhyming Cycle Ergometer ....................................30
2.7.4 Step test .................................................................................31
2.7.5 Field-tests ..............................................................................32
2.8 Periodisation of Training ............................................................33
2.9 Significance of a High Aerobic Capacity to Rugby Players ................33
2.10 Aerobic Capacity Related to Age ................................................35
2.11 Relationship Between Positional Role and VO₂ max .......................35
2.12 Studies in Aerobic Capacity and Team Sports ...............................36
2.13 Summary ..................................................................................40

CHAPTER THREE

MATERIALS AND METHODS
3.1 Introduction .............................................................................41
3.2 Research Design .......................................................................41
3.3 Variables ..................................................................................41
3.4 Location of the Study ...............................................................43
3.5 Target Population .....................................................................43
3.6 Sampling Technique ...............................................................43
3.7 Sample Size .............................................................................43
3.8 Instrumentation ........................................................................44
3.9 Pilot Study .................................................................................45
3.7 Data Collection Procedure .......................................................45
3.11 Logistical and Ethical Considerations .................................47

CHAPTER FOUR

DATA ANALYSES, PRESENTATION AND DISCUSSION
4.1 Introduction .............................................................................48
4.2 Data Analyses Methods and Presentation ....................................48
4.3 Demographic Factors of Players ................................................48
4.4 Aerobic Capacity Values by Teams ............................................50
4.5 Hypotheses Testing ..................................................................56
4.5.1 Aerobic Capacity of Rugby Players Between Pre-test and Post-test 56
4.5.2 Aerobic Capacity Amongst Rugby Players of Different Age Groups 59
4.5.3 Aerobic Capacity Among Impala, Harlequins and Nakuru RFC 61
4.5.4 Aerobic Capacity of Rugby Players by Positions .......................65
CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction ................................................................. 70
5.2 Summary of the Findings .................................................. 70
5.3 Conclusions ..................................................................... 71
5.4 Recommendations ......................................................... 72
5.4.1 Recommendations for Policy and Practice ...................... 72
5.4.2 Recommendations For Further Research ......................... 74

REFERENCES ....................................................................... 76

APPENDICES
Appendix B: Rugby League Final Standings September 2004 .................. 82
Appendix C: The Multistage Fitness Test Procedure .............................. 83
Appendix D: A One Day Rugby Training Activities ............................... 84
Appendix E: Aerobic Capacity Level Evaluation Protocol Sheet .............. 85
Appendix F: A Sample Letter for the Request of Player ......................... 86
Appendix G: Kenya Rugby League Final Standings as per September 2005 .... 87
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 4.1</td>
<td>Impala RFC players’ pre and post-test VO₂ max</td>
<td>51</td>
</tr>
<tr>
<td>Table 4.2</td>
<td>Harlequins RFC players’ pre and post-test VO₂ max</td>
<td>53</td>
</tr>
<tr>
<td>Table 4.3</td>
<td>Nakuru RFC players’ pre and post-test VO₂ max</td>
<td>54</td>
</tr>
<tr>
<td>Table 4.4</td>
<td>Summary of pre and post-test mean VO₂ max Scores</td>
<td>55</td>
</tr>
<tr>
<td>Table 4.5</td>
<td>T-test on players’ VO₂ max between pre-test and post-test</td>
<td>56</td>
</tr>
<tr>
<td>Table 4.6</td>
<td>Summary of VO₂ max by players’ age</td>
<td>59</td>
</tr>
<tr>
<td>Table 4.7</td>
<td>ANOVA for players’ pre and posttest VO₂ max by age groups</td>
<td>60</td>
</tr>
<tr>
<td>Table 4.8</td>
<td>ANOVA for pre and post VO₂ max by rugby clubs</td>
<td>62</td>
</tr>
<tr>
<td>Table 4.9</td>
<td>Tukey HSD teams’ pretest differences</td>
<td>63</td>
</tr>
<tr>
<td>Table 4.10</td>
<td>Tukey HSD for teams’ posttest differences</td>
<td>63</td>
</tr>
<tr>
<td>Table 4.11</td>
<td>Mean VO₂ max summary for the rugby playing positions</td>
<td>65</td>
</tr>
<tr>
<td>Table 4.12</td>
<td>ANOVA summary of VO₂ max on players’ positions</td>
<td>66</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1.1</td>
<td>Factors that cause increased VO$_2$ max</td>
<td>9</td>
</tr>
<tr>
<td>Figure 4.1</td>
<td>Distribution of players by field positions</td>
<td>49</td>
</tr>
<tr>
<td>Figure 4.2</td>
<td>Distribution of players by age</td>
<td>50</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>In full</td>
<td></td>
</tr>
<tr>
<td>-------------</td>
<td>---------------------------------------------</td>
<td></td>
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<tr>
<td>ADP</td>
<td>Adenosine Diphosphate</td>
<td></td>
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<td>ATP</td>
<td>Adenosine Triphosphate</td>
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<tr>
<td>KCB</td>
<td>Kenya Commercial Bank</td>
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<tr>
<td>RFC</td>
<td>Rugby Football Club</td>
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<tr>
<td>VO\textsubscript{2} max</td>
<td>Maximum volume of oxygen</td>
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<tr>
<td>ANOVA</td>
<td>Analysis of variance</td>
<td></td>
</tr>
<tr>
<td>KRFU</td>
<td>Kenya Rugby Football Union</td>
<td></td>
</tr>
</tbody>
</table>
ABSTRACT

The capacity to replenish the energy required for endurance activities is one of the important factors that determine an individual’s ability to exercise for a long time without fatigue. For an individual to attain the best performance, VO2 max improvement is one aspect of training that should not be ignored (Seiler, 2005). This study assessed the aerobic capacity of selected male players taking part in 2005 Kenya Cup Rugby League. Stratified random sampling was used to obtain a sample of 90 male players from Impala, Harlequins and Nakuru RFC. The selection was based on the 2004 final league standings. Quasi-experimental research design was used. A pre-test using the multistage shuttle run test was administered to estimate the endurance capacity of the subjects at the beginning of the competitive season. A post-test was conducted eight weeks after commencement of competition to assess any changes in VO2 max levels. Prediction of players’ maximum oxygen uptake was based on their performance on the Multi-stage fitness test validated by Brewer et al (1998). The computer software package (SPSS) was used to process the data. The descriptive statistics were used to analyse the data. A t-test was used to assess the differences between pretest and posttest, while ANOVA was used to analyse the differences in VO2 max among the three clubs as well as between playing positions. The significant F-ratio was further analysed using Tukey HSD test. The results of the study were presented using graphs and tables. The findings of the study were as follows; there was no significant difference in players’ aerobic capacity between pre-test and post-test. Players’ VO2 max at pre-test was 43.14ml/kg/min and 42.62ml/kg/min at post-test. Similarly, there was no significant difference in aerobic capacity amongst players of different age groups. The findings also indicated that there were significant differences in aerobic capacity among the top (44.5ml/kg/min), middle (40.2ml/kg/min) and the bottom (42.2ml/kg/min) ranked teams. The Tukey HSD test showed significant differences between Impala RFC and Harlequins RFC (5.47*) and also between Nakuru RFC and Harlequins RFC (4.16*) at pre-test. There was also significant difference between Impala and Harlequins (4.23*) at post-test.
CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Aerobic capacity (VO$_2$ max) is the maximum volume of oxygen that an individual’s body can utilize during intense, whole body exercise (Seiler, 2005). In other words, it is the ability of the body to supply oxygen to the working muscles and extract waste products that are transported through the bloodstream and the airways to the atmosphere. Aerobic capacity presents an overall picture of the functional integration of the lungs, heart, blood and, muscles in maximal aerobic work (Powers and Howley 2001).

The ability of the circulation to cope with the needs of active muscles for oxygenated blood is a major limiting factor to aerobic activity. Thus, in a sport with high aerobic demands such as rugby, a large cardiac output is vital for a player. The game of rugby usually consists of about 140 sequences of actions with rest periods of 20 to 40 seconds. This means that for a player to be able to resume the game activity after every stoppage, he must have sufficient aerobic base, which is sustained by enough oxygen that is as a result of a large cardiac output (Reilly, 1996).

According to Seiler (2005), in an aerobic activity, oxygen consumption increases in direct proportion of the intensity until a point is reached when it fails to rise despite increased workload. Further increase of workload after the peak is reached is performed anaerobically. According to Anspaugh et al., (1991), endurance capacity is a physiological adaptation that also regresses due to inactivity. Anspaugh et al., (1991)
further note that athletes in endurance type of sport generally have a higher VO₂ max than other athletes but they would have to maintain it through consistent training.

Despite the importance of aerobic capacity in performance of prolonged activities such as rugby (Reilly, 1996), the Kenyan rugby players’ aerobic capacity had not been evaluated to establish their levels of fitness prior to this study. Although the game of rugby is fast gaining popularity in Kenya, the country still lags behind the top rugby playing nations and performance has been dismal and inconsistent (KRFU, 2004). The KRFU (2004) also notes that Kenya has a small pool of only 600-player base from which players can be selected for local, regional and international competitions. Unlike other sports, rugby involves myriad of technical intricacies, which countries like Kenya are yet to master. Rugby in Kenya is also played on part time basis, with players training only after normal working hours of the day and only two days a week. The most talented Kenyan players also quit playing rugby early, either after high school or in their early twenties due to lack of incentives. KRFU (2004) gives the average age of Kenyan National team as 23 to 24 years most of who retire from competitive play after college.

According to Kenya Rugby Football Union 2004 rugby season fixture, players participated in International Rugby board series four times and four National tournaments namely, Impala Floodlit (4 games), Kenya Cup League (8 games), Eastern Block (1 game) and Nakuru 10 aside (2 games) per rugby competition season. In total, this added up to 4 matches at international level, and 12 matches at National level per competitive season. This equaled to 1280 hours of competitive play for the player who participated in all these tournaments during the seven months long rugby season. Despite these hours of competitive play, there is only one month long pre-
season period available for the players' physical conditioning. Physical conditioning mainly involves fitness activities with the ball, with an emphasis on speed and recovery. However players do not train as one squad because they report for training at different times. Players are only available in the evenings after their daily occupational routines (Mundia, 2004).

Hazeldine and Holmyard (1993) explain that the league structure also places greater performance demands upon rugby players especially those in the national squad. This is because players in the national team are expected to perform at consistently higher level for approximately 30 weeks of the 35 weeks rugby season.

According to Mundia (2004), Kenya Rugby Union League is played on home and away bases starting from the months of April to early September. This calls for a player to have a high aerobic power base. There is therefore a need to maintain performance and fitness levels to prepare players for intermittent sprinting with low recovery periods that characterize the game. Frequent training therefore is necessary to provide a more effective stimulus to the oxygen transport system (Seiler, 2005). Reilly (1990) suggests that training should be evolved from a thorough analysis of the demands of the game taking into consideration that players have different roles to play during the game. Reilly (1990) further notes that performance in rugby depends on the tactical considerations, interplay of players in tactical moves, proficiency in skills of kicking, catching, passing and those that are specific to positional role
Despite the importance of the aerobic capacity, Kenya rugby players had not been evaluated on this physiological parameter hence the importance of this study in order to avail such data and provide feedback to players on their endurance fitness levels.

1.2 Statement of the Problem

Aerobic processes provide the energy for endurance activities such as rugby. However, if a player’s aerobic endurance is inadequate, production of lactic acid commences at extremely low level of energy expenditure, resulting in premature fatigue (Maughan, and Gleeson, 2004). In order to improve aerobic endurance, it is necessary to increase either the total capacity or the maximum output of the appropriate energy sources. This can be achieved by emphasizing the type of endurance relevant to rugby players (Gabbett, 2000).

A study by Gabbett (2000) using amateur rugby league players reported a drop in general physical fitness and aerobic capacity as a result of competition-oriented training and prolonged competitive period. The Kenya Cup league season runs over a period of five months with teams playing a game every weekend. During the competitive season, there is limited time for fitness preparation coupled with limited recovery time between matches. This can adversely lead to decline in players’ fitness levels throughout the playing season. It was therefore, necessary to establish whether the aerobic capacity of the players changes due to emphasis on in-season training competition.

The KRFU (2004) has also observed that lack of professional league and lack of incentives leads to Kenyan rugby players’ failure to turn up for training regularly. Lack of professional league means that, players do not get adequate time to train. Likewise
insufficient fields may interfere with players’ frequency in turning up for training on regular basis. However, as observed by Seiler (2005), aerobic capacity improves when duration, frequency and intensity of training are taken into consideration. Wan-jiku (2003) conducted a study on aerobic capacity of a selected soccer premier league teams and concluded that the teams that ranked high had also the highest VO$_2$ max levels. The study however did not measure the aerobic capacity of rugby players hence the necessity for this study in order to give coaches and players’ vital information on the physiological profiles that would serve as a point of reference when drawing up training programmes for the rugby players.

1.3 Purpose of the Study

The purpose of the study was to assess the aerobic capacity levels of players participating in 2005 Kenya Cup League, with a view to providing coaches and players with relevant information to assist in designing suitable training programmes. The study also sought to find out whether the aerobic capacities of the players vary with age, playing position, as well as with teams’ ranking.

1.4 Objectives of the Study

The objectives of the study were:

i) To compare the pre-and post-test measurements of aerobic capacities of the 2005 Kenya Cup League players.

ii) To compare the aerobic capacity of players of different age groups participating in the 2005 Kenya Cup League.

iii) To examine the aerobic capacity of the top, middle and the bottom ranked teams according to their performances in 2005 Kenya Cup League.

iv) To find out the aerobic capacity of the forwards and backs in 2005 Kenya Cup League.
1.5 Research Hypotheses

The study tested the following hypotheses:

i) There was no significant difference in aerobic capacities of Kenyan rugby union players between pre-test and post-test measurements.

ii) There was no significant difference in aerobic capacity amongst players of different age groups participating in the 2005 Kenya Cup League season.

iii) There was no significant difference in aerobic capacity among the top, middle and bottom ranked teams in the 2005 Kenya Cup League.

iv) There was no significant difference in aerobic capacity between forwards and backs in 2005 Kenya Cup league.

1.6 Significance of the Study

The essence of rugby is the ability to sustain high levels of skill at a high-speed intermittent activity over the 80 minutes game duration. The background against which skills can be achieved and translated into good performance is through maintenance of endurance fitness throughout the season. Endurance fitness enables the players to retain the quality of play and also reduces chances of injury. Despite the importance of aerobic capacity, and the fact that the game of rugby is also gaining popularity in Kenya, there is very little research done on this fitness parameter on players in various games in Kenya, and specifically in rugby.

This study therefore provides important data on aerobic capacity of Kenya rugby players. The research findings will be useful to the coaches in designing training programmes that are not only relevant to individual rugby players’ endurance but also position-specific. This will in turn enable the players to meet the demands of the game in their specific roles. The physiological profile of the players also avails the
necessary information on the starting level of training the rugby players. This then makes it possible for the coaches and the players to participate in optimal training programmes.

Additionally, the research findings may raise the morale of the players since they endeavor to improve their fitness and therefore turn up for training regularly. Coaches and players may use the VO₂ max data and skills acquired to routinely evaluate and monitor the training programmes and where necessary, adjust them to suit individual/teams’ needs.

The information obtained on players’ aerobic capacity is beneficial for scholarly purposes and for further research in sports science in general. The study availed data that is useful for the comparison of Kenyan rugby players/teams with those from other parts of the world.

The study findings are a reference point from which other parameters of rugby players’ fitness levels can be assessed for the purpose of game development. So far Kenya’s performance in rugby has been dismal and inconsistent (Punter, 2005).

1.7 Limitations of the Study
i) The researcher had no control over the players’/teams’ training programme.
ii) The researcher had no control over the players’ nutritional habits.
iii) The researcher had no control over the players’ health status.

1.8 Delimitations of the Study
i) The study was delimitated to male rugby players of randomly selected teams participating in 2005 Kenya cup league.
ii) The study only assessed the aerobic capacity as an indicator of cardiovascular endurance using the validated progressive 20 meters multistage shuttle run test. Although other physiological parameters of rugby player are important, aerobic fitness is paramount because fatigue not only can compromise execution of skills but can also interfere with players' coordination and may even cause injuries.

1.9 Assumptions of the Study

This study was based on the following assumptions:

i. All players were in good health.

ii. All players were taking balanced diet.

iii. All players received adequate and appropriate training to enable them compete in the league.

iv. All players received instructions from a qualified coach/trainer.

1.10 Conceptual Framework

According to Seiler (2005), a great measure of oxygen consumption during exercise is an indication of muscles working at a higher intensity. An endurance athlete would require efficient oxygen delivery and mitochondria rich-muscles to use the oxygen and support high rate of exercise (Astrand and Rodahl, 2003). Seiler (2005), however, notes that, delivery of oxygen is a major limiting factor to aerobic capacity because even the best-trained muscles cannot use oxygen that has not been delivered. Seiler (2005) explains that if oxygen is delivered to muscles that are poorly trained for endurance, VO$_2$ max will be lower despite a high delivery capacity. He further notes that during the test for endurance, untrained athletes stop at a point in the test when the VO$_2$ max seems to still be on the way up.

This is an indication of low aerobic capacity in the working muscles thus leading to local fatigue prior to full exploitation of the cardiovascular capacity. Tests on endurance athletes also show a gradual plateau of the VO$_2$ max despite increasing intensity
towards the end of the test after which they experience fatigue and cannot go further with the exercise (Hampson, 1998)

Fig. 1.1: Factors That Cause Increased VO\textsubscript{2} max (Adapted from Powers and Howley, 2001)

Figure 1.1 shows cardiovascular functions that are involved in the transportation of oxygen to the active muscles as well as the factors affecting the capacity of muscles to utilize oxygen. These factors often result in considerable differences in VO\textsubscript{2} max among different populations before and after engaging in a training programme designed to improve endurance (Powers and Howley, 2001). Endurance training leads to increased stroke volume resulting in increased cardiac output. Increased cardiac output in turn allows more oxygenated blood to reach the active muscles where extraction of oxygen is also enhanced as a result of increased muscle capillary density
and mitochondria. Improved oxygen utilization due to aerobic training is reflected by increased arterial-venous oxygen difference, which is an indicator of increased VO₂ max.

Seiler (2005) is of the view that during competition, the limitation in performance depends on the muscles ability to supply energy and efficiency of oxygen delivery system. Players displaying better skills but lacking in endurance capacity experience early fatigue. Fatigue in turn may interfere with players’ coordination, ability to execute skills and may also lead to injuries (Reilly, 1996). Similarly, a period of inactivity due to injury as noted by Anspauh et al., (1991), lowers the aerobic capacity of all individuals irrespective of the sport one participates in. This is due to reversal of the adaptations to the muscles and the cardio respiratory organs.

1.11 Operational Definition of Terms

Aerobic Capacity: The maximum volume of oxygen consumed by the body each minute during a rugby match in the Kenyan Cup Rugby Union League. Aerobic capacity for players in various sports has been found to normally range from 26.8ml/kg/min to 88.2ml/kg/min (Astrand and Rohdal, 2003). This has been established through their performance on the progressive multistage shuttle run test. Aerobic capacity is synonymously used with some other terms including, endurance capacity, the VO₂ max, and aerobic fitness/ endurance.

Back: This refers to any of the seven back players in a game of rugby who are mainly the ball carriers. They include the scrum half, the fly half, inside center, outside center, two wingers and one fullback (positions 9-15).

Forward: This refers to any of the eight players in a game of rugby who are usually the ball winners. They include two props, one hooker, two locks, two flankers and the 8th-man” (positions 1-8).
Kenya Cup Rugby Union League: An annual competition currently involving seven male rugby teams in Kenya.

Multistage Shuttle Run Test: It is a progressive shuttle run test used in this study for the prediction of maximum oxygen uptake of the rugby players participating in the 2005 Kenya Cup League.

Rugby player: A player who participates in Kenya Cup League as a forward or a back.
CHAPTER TWO
REVIEW OF RELATED LITERATURE

2.1 Introduction
Outlined in this chapter is the information pertaining to maximal oxygen uptake, factors that determine aerobic capacity, physiological changes due to training, measurements of aerobic capacity, significance of a high aerobic capacity to rugby players, relationship between positional roles in rugby and VO2 max as well as various studies on aerobic capacity.

2.2 Maximum Oxygen Uptake (VO2 max)
Maximum oxygen uptake is the highest volume of oxygen an individual uses during exhaustive work. An individual’s maximal volume of oxygen consumption is the best measure of aerobic fitness (Seiler, 2005; Astrand and Rodahl, 2003). It is the best indicator of efficiency of the cardiovascular system in providing large quantities of oxygen to the cells during work and removal of large quantities of lactic acid. This view is also expressed by Bryant (1999) that VO2 max as an indicator of aerobic fitness involves optimal ability of the three systems namely, pulmonary, cardiovascular and muscular to take in, transport and utilize oxygen. Thus the higher the VO2 max, the greater the level of physical activity.

Astrand and Rodahl (2003) note that, great oxygen uptake potential is probably an inherited factor. This means that an individual with VO2 max of 45ml/kg/min to 50ml/kg/min may never be able to reach the required oxygen uptake levels to become an elite Olympic champion in an endurance event. According to Fisher and Jensen (1990) athletes with high VO2 max generally work at a faster rate than those with low oxygen uptake. This is because the greater oxygen uptake allows the body
to utilize the more efficient energy producing pathways and a larger circulation to the cells.

2.3 Determinants of Aerobic Capacity

Aerobic capacity is a major component of fitness in both an adult and a youth. To a large extent, aerobic capacity is dependent on and limited by the ability of the cardiovascular system to deliver oxygen to the working muscles. The lungs, heart, quality and quantity of blood, circulatory system, and cellular components that help the working muscles utilize oxygen are all factors that determine aerobic capacity (Baumgartner and Jackson, 1999). Bernhardt (1986) also observes that aerobic training serves as a base for all sports and physical activity. Adaptation due to aerobic training depends on the following factors.

2.3.1 Initial Level of Fitness

An athlete with low initial level of fitness records high VO\(_2\) max improvement values after undergoing training while those with high aerobic capacity record lower values of improvement after undergoing training (Wilmore and Costil, 2004). In other words, the lower the initial level of fitness the greater the percentage of VO\(_2\) max increase after training. Gains of an average subject can be between 10 and 20 percent while a well-trained subject gains are made at much lower rates (Powers, and Howley, 2001).

2.3.2 Intensity

Bernhardt (1986) and McLatchie (2000) observe that training effect depends on the amount of stress imposed upon the relevant part of the body. They explain that, the intensity of 60% to 80% VO\(_2\) max is recommended for aerobic capacity improvement. However, Powers, and Howley (2001) explain that, intensity is so relative such
that, a certain level of intensity may be easy for one person and hard or too high for another. Hence people respond differently in similar training programmes.

Reilly (1996) has explained that the training workload should also be taken into consideration since forward and back players require varying workloads. This is because each positional role in rugby has unique demands with type and frequency of training varying markedly with the level of play. According to Foss and Keteyian (1998), for an athlete to benefit from training improvement, the intensity of training should take into consideration the amount of workload relevant to specific body organs overloaded during the activity.

However the intensity of the workload required to produce an effect on fitness should also be increased as the performance is improved in the course of training and competition. Training is therefore relative to the level of fitness of the individual player. The magnitude of the training load should also vary from one individual to another (Maughan and Gleeson, 2004).

2.3.3 Duration

According to Fahey (2001), there is a great improvement in VO₂ max with increased duration of training period. This was observed in a study on athletes of average fitness using duration of 15, 30, 45 minutes. The 45 minutes duration resulted in a higher VO₂ max Corbin et al., (2002) advanced the idea that when players train for several competitive events such as games or matches during sports season, it requires careful planning and periodisation of training in order to reach the peak performance at the right time and to avoid injuries.
Corbin *et al.*, (2002) are of the view that training activities should be planned in such a way that there are periodic peaks and valleys during training programme to allow the body to adapt and recover. The rugby coaches and players should therefore ensure that over the course of the season, there is a gradual progression in training that would allow the players to peak at just the right time. To accomplish this, Corbin *et al* (2002) suggest that training should begin with an emphasis on base training for aerobic endurance where volume of training is increased gradually. They note that as the season progresses, the intensity should be increased and volume reduced since high intensity activity requires more time for recovery.

### 2.3.4 Frequency

According to Maughan and Gleeson (2004) training for only one day per week does not produce improvement in aerobic fitness while training for 3-5 days per week for duration of 30 minutes produces greater gains. He observes that improvements are also greater when training is done on consecutive days. However, players’ occupation can interfere with the maximal aerobic capacity. Players whose daily tasks are physically demanding have their training oxygen transport system invigorated. On the other hand, the more mechanized the society has become; the less pronounced the differences may be between individual occupations (Astrand and Rodahl, 2003).

### 2.3.5 Mode of Training / Specificity

In order to improve an individual’s ability to perform an activity, training program should involve working specific muscles or organ systems at an increased resistance (Foss and Keteyian, 1998). The activities should simulate as closely as possible the movement patterns required to perform the specific sport. This would develop aerobic energy system within the muscles needed to perform the specific sport. This is because effects of the training are confined to those body systems or parts of the sys-
tem, subject to the overload. These views are expressed by Lambrinides (2000) that training does not transfer well from one activity to another.

Observations by Foss, and Keteyian (1998) indicate that greater demands for oxygen transportation arise when large muscle mass contracts in exercise. They further indicate that activities such as cycling and running are the most suitable for developing aerobic fitness since these place great stress on the heart and circulatory mechanisms. Research findings by Foss and Keteyian (1998) on three categories of athletes namely, rowers, cyclists and skiers after first determining their VO\textsubscript{2} max on a treadmill revealed an improvement of 3% to 5% higher than their original values after they were tested while performing their specific sport.

2.3.6 Overload

Heyward (2002) explains that for a training programme to be effective, it must satisfy the principle of overload. Training must impose a work stress greater than that experienced in everyday life and should be gradually increased sufficiently as the athlete adapts to training. For example, if a person can lift 80kg with a particular muscle group, it would be of little benefit to continue to train with 50 percent of the same load. In every individual there is definite intensity of effort or overload threshold below which, no training effect occurs (MacClatchie, 2000).

In a game of rugby there is less homogeneity among the positional roles and therefore each individual demands unique workload specific to the position occupied in the field besides other tactical considerations. On the overall, the game requires a mixture of fast reactions, speed, agility, muscular strength, anaerobic and aerobic power, but not in a clearly defined way (Reilly, 1996).
2.3.7 Age

Aerobic fitness is age-dependent, steadily increasing during childhood and reaching the peak at about age 25 years, after which it slowly declines (Astrand and Rodahl 2003). A longitudinal study by Astrand and Rodahl (2003) using subjects with high level of habitual physical activity revealed that the maximal heart rate declined from an average of 195 beats per minute when they were in mid twenties to 176 beats per minute thirty three years later. However the study did not reveal good correlation between the decline in maximal oxygen uptake and the change in individuals’ maximal heart rate.

Generally, the aging person becomes less physically active, which inevitably lowers maximal aerobic capacity (Astrand and Rodahl, 2003). According to Fisher and Jensen (1990) loss of endurance at any age can be reduced significantly as a result of training. They point out that, the maximum endurance once reached is held fairly constant for three to five years in a training athlete. Endurance then wanes gradually because of several changes that occur in the respiratory and circulatory systems with increased age.

Fisher and Jensen (1990) also point out that increases in pulmonary ventilation from young age to adulthood are primarily caused by physical maturation. Conversely, a drop in pulmonary ventilation of a young adult occurs due to inactivity, which leads to a decrease in the expiratory volume, inspiratory volume and the vital capacity. Inactivity also causes the reduction of elasticity in the walls of the thoracic cage. All these translate into less oxygen reaching the working muscles hence reduced aerobic capacity.
2.3.8 Gender

Until the beginning of puberty, girls are about equal to boys in VO₂ max. However, after puberty the female aerobic capacity is only about 70% to 75% that of the male. Women reach maximum endurance potential at about age of 20 years while men continue to increase until mid-20s (Astrand and Rodahl, 2003). Females generally have more adipose tissue compared to males and since fatty tissue is metabolically fairly inert, the females' VO₂ max is usually low compared to that of the male counterparts (Astrand and Rodahl, 2003). Low maximal oxygen uptake in women is also attributed to lower hemoglobin concentration that leads to a less oxygen carrying capacity to the working muscles (Foss and Keteyian, 1998).

2.3.9 Individual Differences and Training

According to Foss and Keteyian (1998), research evidence supports the concept that genetic factors are associated with individual differences in VO₂ max. However, reaching one's maximum aerobic potential can only occur through aerobic endurance training. Anspaugh et al., (1991) have advanced the same idea that genetic potential, diligence and knowledge of training result in performance of great feats of endurance. These sentiments are supported by Lambrinides (2000) that, genetic factors probably establish the boundaries of an athletes' endurance, but training can push VO₂ max to the upper limit of these boundaries. Since each individual is biologically unique, training principles should be tailored to individual needs especially where combination of skill and aerobic fitness is demanded. Astrand and Rodahl (2003) have further noted that most people are average in endurance and cannot compete with the specially endowed ones. However, every person can achieve aerobic potential with endurance training.
According to research findings by Astrand and Rodahl (2003), an athlete broke the world records in middle and distance running in 1940 at a time when his body weight was 69 to 70 kg. At the age of 45 years, (23 years later) in 1963 his heart rate and oxygen uptake were recorded while exercising on Bicycle ergometer. His maximal oxygen uptake was 4.0 liters per minute, 181 heartbeats per minute and blood lactate of 13.8 mm per minute while his body weight was 94.5 kg. Although he had not trained since 1946, his recorded high maximal aerobic capacity is an indication that given favorable endowment, untrained individuals can maintain high aerobic power.

Wilmore and Costil (2004) reckon that there is no universal formula for training and success in any given sport and therefore physiological basis for training to enhance aerobic capacity must consider the aforementioned factors. Reilly (1996) further points that, rugby being a multiple sprint sport, players’ fitness should be assessed in terms of one’s ability to repeat maximal sprints between short recovery periods with minimum fatigue.

Reilly and Secher (1990) support the view that, although genetic factors are important in most sports, a high standard of training is essential and that even inherited traits need to be nurtured for sporting potential to be realized. Individual players endowed with possibility of obtaining high oxygen uptake should compliment it with rigorous training in order to achieve maximal performance. This would develop the player’s ability to sustain a high utilization of their maximal oxygen uptake translating into physiological efficiency in performance. This view is supported by Foss and Keteyian (1998) where they note that, just like the less genetically endowed counterparts, the level of success or performance that those genetically endowed enjoy will
only be achieved through personal commitment to a long term, well-planned training regimen.

2.4 Physiological Adaptations Due to Training

According to Maughan and Gleeson (2004), peripheral and central variables may be limited or enhanced by aerobic training. Furthermore, an understanding of chronic metabolic responses to training is necessary in order to design training programmes based on sound physiological principles.

2.4.1 Peripheral Adaptations Due to Training

Once oxygen has been delivered, the working muscles must be able to sustain physical performance. Training activities that promote cardiovascular fitness also stimulate changes in the muscles making them more effective in utilizing oxygen. The ability of the working muscles to extract oxygen from the blood improves greatly due to endurance training (Seiler, 2005). Cellular changes that bring about this improvement include:

a) Increase in Myoglobin Content- increase in myoglobin content of the skeletal muscles enhances the rate of oxygen transport. It also increases oxygen utilization in the muscle by increasing oxygen diffusion through the cytoplasm of the cell into the mitochondria (Berger, 1982). According to Foss and Keteyian (1998), myoglobin content of the skeletal muscle has been shown to increase by as much as 75% to 80% but only in muscles exerted during a training program. The level of myoglobin increase also depends on the frequency of training. Greater increases are recorded when intensity of training is more than three days per week (Corbin et al., 2002).

(b) Increase in Number and Size of Mitochondria- Berger (1982) states that approximately 50% of the increase in oxygen consumption by the body after training is due to the increase in myoglobin content and size of mitochondria. This leads to in-
creased generation of ATP and increased oxidative capacity of the trained muscles. Increased size and number of mitochondria means that less ADP would be needed to increase ATP production and VO\textsubscript{2} max to a given level after training. Mitochondria will also be activated less to produce the same amount of ATP (Foss and Keteyian 1998).

(c) Increase in Oxidative Enzymes- According to a study by Henriksson and Hickner (1994), the enzymes of fatty acid oxidation, citric acid cycle and respiratory chain increased three fold in the thigh of a trained athlete compared to the untrained individual. Powers and Howley (2001), hold the view that there are greater changes in muscle oxidative enzymes with training than changes in VO\textsubscript{2} max. Oxidative enzymes are found to increase by 50-100% while the VO\textsubscript{2} max only increases by 40-50%. This suggests that a circulatory factor (O\textsubscript{2} delivery) rather than oxygen utilization is a limiting factor. The level of habitual activity influences metabolic enzymes and would result in increased storage of muscle glycogen that is vital for enhancing performance in prolonged activity (Maughan and Gleeson, 2004).

(d) Increased Skeletal Capillarization- Leonard (1994) reckons that, two months of training at high sub-maximal intensities are sufficient to increase the total number of muscle capillaries by 50 per cent. High capillary network translates into more blood being accommodated in the vascular bed per unit of time thus allowing a complete exchange of substrates by reducing mean transit time. This in turn facilitates and increases the extraction of oxygen by the working muscles leading to enhanced aerobic capacity.

A study by Astrand and Rodahl (2003) revealed that there is a high correlation between the capillary density in the skeletal muscle and their maximal oxygen uptake. By counting the number of capillaries per fiber per mm\textsuperscript{2} in biopsy samples from the
vastus lateralis of the quadriceps muscle in untrained and trained individuals, they found out that the number of capillaries per fiber was 32% greater in the trained versus the untrained group. The study findings showed a high significant difference of $P < 0.001$ that was almost of the same order of magnitude as the difference in oxygen uptake between the two groups, namely of 40%.

Reilly (1996) emphasizes that in a team game, players should be programmed to train specific muscles mostly used in their different positions during a match. This would ensure that relevant skeletal muscles develop increased blood capillaries to supply sufficient oxygen during the game to enable individuals to perform without undue fatigue. The increased capillaries in the working muscles not only provide good facilities for the supply of oxygen and nutritive materials to the working muscles but also ensure the fast removal of the by products of the metabolic activity such as carbon dioxide and lactic acid that would otherwise lead to fatigue.

(e) Increased Oxidation of Fat- Fat is a major source of fuel for skeletal muscle during the endurance activities; therefore any increased capacity to oxidize fat would be an added advantage in increasing endurance. A study by Foss and Keteyian (1998) found out that with endurance training, there are increased muscle triglycerides stores within the skeletal muscle cells as well as the intramuscular fat stores. Fatty acid oxidation is primarily due to increased mitochondria enzymes that activate and oxidize fatty acids in the Krebs cycle and electron transport chain. This leads to a slowed utilization of glycogen stores by working muscles, thereby preventing the depletion of glucose that would otherwise limit prolonged exercise. There is also the benefit of less lactic acid accumulation, a by-product of anaerobic combustion hence less muscular fatigue (Bernhardt, 1986).
(f) Recruitment of Slow Twitch Muscle Fibers- Berger (1982) points that in continuous and prolonged sub-maximal work, the slow twitch Type 1 muscle fibers are mostly recruited. In order to improve the ability to repeat severally the burst-type activities as is required of a rugby player, the slow twitch Type 1 muscle fibers should be exercised more because their biochemical activity largely limits performance in endurance events.

Kaiser (2005) notes that slow twitch muscle fibres contain more mitochondria and myoglobin that make them more efficient at using oxygen to generate energy without lactate build up. This muscle fibre type can thus go for a long time before getting fatigued, which is important for an endurance sport. Slow twitch fibres also produce contraction force more rapidly than fast twitch fibres and this makes them an asset to power based players when there is limited time to generate maximal force. MacDougal et al., (in Reilly and Rodahl, 2003) carried out a study using seven healthy male subjects observed under control. After 5 to 6 months of training followed by 5 to 6 weeks of immobilization in elbow casts, cross section fiber areas were calculated from sections of muscle biopsies taken from triceps brachii. The study revealed a 100% increase in maximal elbow extension strength and a significant increase in both fast twitch and slow twitch muscle fibers. Immobilization also resulted in reduced strength by 40%, and reduction in fiber areas above 30% and 25% for the fast and slow twitch fibers respectively. These findings are an indication that prolonged inactivity especially during off-season as well as lack of enough training load can be detrimental to the aerobic capacity and can lead to reduced performance during competitions as observed by Reilly (1996).
2.4.2 Central Fitness

Anspaugh et al., (1991) and Corbin et al., (2002) are in agreement that good aerobic fitness is dependent on a well-conditioned heart muscle and vascular system. This in turn guarantees efficient delivery of oxygen from the blood to the active muscles. To accomplish this vital task, a strong heart muscle is required as well as elastic arteries free of obstruction and adequate number of healthy capillaries. The following are the factors emanating from a well-adapted central circulation:

(a) Stroke Volume- Foss and Keteyian (1998) observed that the amount of blood that the heart can eject in one heart beat increases mainly due to increase in the size of the ventricular cavity resulting in greater filling of the heart. The contractile strength of the ventricular wall also forcefully ejects a greater amount of blood (Anspaugh et al., 1991). This also agrees with Fisher and Jensen (1990) who indicate that the greatest stroke volume occurs during work because of the increased vigor and strength of the ventricular contraction, which yields a more complete emptying of the ventricle.

(b) Cardiac Output- During exercise, cardiac output increases with the increase in oxygen uptake but not linearly (Powers and Howley, 2001). According to Anspaugh et al., (1991) the cardiac output increases from 6 liters per minute at rest to 25 liters per minute during maximum exercise for an average person. They further point out that the cardiac output of 40 liters per minute for a large, well conditioned athlete is a common element. During a strenuous activity, more blood is diverted to the active muscles for extraction of oxygen. The oxygen dissociation curve is shifted so that oxyhaemoglobin is reduced, thus availing more oxygen to the working muscles.

According to Fisher and Jensen (1990), there is strong evidence that, a large cardiac output capacity is inherited and is also related to ventricle size. They note that al-
though ventricular size can probably be increased through training, the large stroke volume values may never be reached without some genetic help.

(c) **Heart Rate**—Watson (1995) confirms that, a few months of aerobic training lowers the resting heart rate by 10 to 25 beats per minute. A slow activity might produce a heart rate of 165 beats per minute prior to training and 140 beats per minute after a few months of training (Anspaugh et al., 1991). Foss and Keteyian (1998) also observe that, endurance training leads to faster heart rate recovery after a heavy exercise and that a resting heart rate of 40 beats per minute is common with highly trained athletes. Furthermore, the trained athlete’s slow heart rate coupled with large stroke volume allows the heart muscle to require less oxygen, which is an indication of cardio respiratory efficiency. They however state that these changes are as a result of a long duration / or years of intensive training.

(d) **Blood Volume**—Aerobic endurance increases blood volume and the number of red blood cells. This adaptation lowers viscosity of the blood allowing it to flow more easily through circulatory system (Wilmore and Costil, 2004). Additional blood volume increases the capacity of the circulatory system to transport substances to and from the working muscles (Anspaugh et al., 1991).

When done regularly, endurance activities can lead to a permanent increase in the amount of circulatory volume (Seiler, 2005). According to Anspaugh et al., (1991), a physically fit man can increase his oxygen uptake from 0.25 to 5.00 liters per minute or more when exercising on a cycle ergometer or treadmill. This is an indication that if an athlete maintained aerobic fitness it would be possible to sustain high cardiac output during an activity to sufficiently support the metabolic demands of that activity (Baumgartner and Jackson, 1999).
2.5 Energy Requirements for a Rugby Player

The demands of a rugby game include acceleration, changing direction, short sprinting, fast striding, slow jogging, using upper body strength, rapid recovery and an interchange amongst any of these activities. As a result, all energy systems are placed under certain degree of demand. A rugby player thus needs to be an all round athlete who is endowed with the following energy systems (Kaiser, 2005).

a) Short-term Energy System

Phosphocreatine produces most of the energy required during a maximum exercise lasting 20 seconds. Creatine phosphate is found in the muscle fibres while strength and acceleration are predominantly attributed to fast twitch muscle fibres. Short-term energy supply is central to performance of the forwards during a whole rugby game and to the backs for short periods of the game. The primary role of the forwards is to accelerate at the opposing players to break the defensive line in order to gain distance to the try line. The backs role is to sprint past the opposition with speed in order to make scores (Kaiser, 2005).

b) Intermediate Energy

This provides the energy required for a sustained performance lasting between 20 seconds and 2 minutes. This is critical to a rugby player during the whole game. Muscle glycogen in the muscles is the initial substrate while the end product is lactate. This energy system cannot sustain maximum sprinting speed needed but lasts a bit longer before intensity is further reduced. Since no oxygen is involved, build up of lactate causes fatigue and hampers players’ performance. Much of the rugby game consists of continuous wrestling of opposing players to the ground in order to halt their progress to the defending teams’ try line. This activity thus places greater demands on the anaerobic glycolysis (Kaiser, 2005).
c) Long-term Energy System

The aerobic energy system is not a major source of energy during most of the competitive phases of rugby match, but since the game lasts 80 minutes, nearly all the energy provided by the other energy systems must be paid for before the match is over. Delivery of the oxygen to the fatigued muscles replenishes stores of creatine phosphate and lowers levels of the lactic acid. This is important especially to the backs that are required to cover the greatest distance during the game. A good supply of oxygenated blood allows the muscles to expend more energy over a long period of time thus increasing performance (Kaiser, 2005).

2.6 Pulmonary Ventilation and Metabolic Demands

Metabolic needs of the body are reflected by the amount of respiratory activity. As work increases, oxygen demands by the active tissues increase. Pulmonary ventilation is elevated to supply sufficient quantity of oxygen and to remove carbon dioxide. During heavy work, both the metabolic demands of the tissues as well as the pulmonary ventilation increase though not linearly (Berger, 1982). This rise of ventilation during exercise is an indicator of oxygen needs by the muscles. The steeper the rates of increase in ventilation, the greater the metabolic demands of the tissues and the consumption of oxygen. This positive relationship between the ventilation and oxygen consumption allows an estimation of VO$_2$ max from the liters of air moved in and out of the lungs (Fisher and Jensen, 1990).

According to Berger (1982), improved strength and endurance of the chest muscles that assist in breathing may lead to increase in vital capacity and reduced residue volume of the lungs. Ventilation would also increase with maximal effort. Berger (1982) further observes that smoking habits in a player can drastically affect the
pulmonary ventilation. He notes that inhaled smoke causes 2 to 3 fold increase in airway resistance after several seconds lasting 10 to 30 minutes. The bronchures constrict making breathing more labored during the exercise thus raising the oxygen cost of ventilation to about twice that of non-smokers. Besides, less hemoglobin will be available to deliver oxygen because they have a high affinity for carbon monoxide than for oxygen. The result is less oxygen in circulation and in the working muscles hence reduced aerobic capacity leading to early fatigue and reduced performance.

2.7 Measurements of Aerobic Capacity

Aerobic capacity in terms of maximal oxygen uptake can be determined with a reasonable degree of accuracy using laboratory procedures and cooperation from the subjects. These laboratory methods are fairly laborious and require expensive equipment that may not be readily available to all coaches and players. However there are different reliable methods of assessing aerobic capacity using either field tests or laboratory measurements (Heyward, 2002). In these tests, Maximum oxygen uptake (VO₂ max) is measured by gradually increasing the workload until an additional work increment does not elicit more oxygen consumption. The VO₂ max reaches a plateau and then remains steady (Watson, 1995). Maximum aerobic capacity can only be reached if the test sufficiently overloads the physiological mechanism or exposes the player to stresses greater than those encountered in daily activities (Bernhardt, 1986).

According to Powers and Howley (2001), the usefulness of a test is a function of both accuracy of measurement and the ability to repeat the test on a routine basis to evaluate changes in VO₂ max over time. If athletes for example took aerobic fitness test regularly and their results show that the heart rate is decreasing over time, this
would help them appreciate the progress and be motivated to train regularly. The result of individual’s maximal aerobic capacity therefore provides a new basis for selection of fitness activities and revision of activity programme. According to Astrand and Rodahl (2003), any test for maximal oxygen uptake should as much as possible meet of the following general requirements: (i) the exercise should involve large muscle groups, (ii) the rate must be measurable and reproducible, (iii) the test conditions must be such that the results are comparable and reproducible, (iv) the test must be withstood by all healthy individuals, (v) the mechanical efficiency (skill) required to perform the task should be as uniform as possible in the population to be tested.

Seiler (2005) and Hampson (1998) also agree that whether one uses a field or a laboratory test to measure aerobic capacity, oxygen consumption will increase with increasing workload until it reaches a plateau, after which any further work is performed anaerobically. Some of the tests that produce reliable estimates of maximal oxygen uptake include 1-mile walk test, 3-minute bench step test, 1.5-mile run-walk test, Astrand and Rhyming bicycle ergometer test and coopers’ 12-minutes run test (Faheh et al., 2001). The most accurate laboratory assessment tests include direct calorimetry, motorized treadmill and cycle ergometer in that order (Powers and Howley 2001).

2.7.1 Direct Calorimetry

This is the most accurate method of determining maximal oxygen uptake. $VO_2$ max is measured by increasing the power output linearly until the subject reaches exhaustion. The expired gases are collected during exercise. The $VO_2$ max is computed by measuring the oxygen and carbon dioxide concentration of the room and expired air
and volume of expired air per minute. Though accurate, this method is expensive in terms of equipment and technical personnel hence it is not commonly used under field conditions (Heyward, 2002).

2.7.2 Motorized Treadmill

According to Powers and Howley (2001), a treadmill provides the greatest potential load on the cardio respiratory system at a set pace. A running treadmill gives higher values of estimated VO2 max than the walking treadmill test protocol. Treadmill uses the natural activity of running and walking and can be used by the less fit and most fit individuals. It can be maximal or sub-maximal test. The grade and the pace must be correctly set and the subject should be able to follow instructions.

There are several treadmill protocols but the most commonly used is Bruce protocol. It is a non-linear protocol where power output is systematically increased by time and the elapsed time to reach exhaustion is an index of maximum work capacity. Treadmill measures are reproducible since the pace for the subject is machine set. However the machine is expensive, is not portable and does not facilitate measurements of heart rate and blood pressure (Baumgartner and Jackson, 1999).

2.7.3 Astrand and Rhyming Cycle Egormeter

This is a single stage exercise test and is considered more accurate than multistage model. The subject is required to complete a workload of approximately six minutes. This elicits a heart rate of between 125 to 170 beats per minute. The subject should find the most comfortable peddling position. A metronome is used to standardize the peddling rate (Baumgartner and Jackson, 1999).
For less fit and smaller people, workloads of 300-600 are recommended. A peddling rate of 50 revolutions per minute and a workload of 750-1,200 kpm are appropriate for larger and fitter people. If the heart rate is in the correct range during the 6th minute, the heart rate is counted for the entire 6th minute using carotid or radial pulse.

The nomogram is used to estimate the VO₂ max based on the subjects’ heart rate response during the 6th minute work rate. The rationale for the test is that if an individuals’ heart rate were known at 50% VO₂ max, then the VO₂ max would be twice the figure recorded at 50% heart rate (Baumgartner and Jackson, 1999).

2.7.4 Step Test

Corbin et al., (2002) explain that the step test estimates VO₂ max in the same way as the treadmill and cycle ergometer protocols and can be used for both maximal and sub maximal testing. One is required to have a 12-inch bench and a metronome. The subject steps up and down the bench for 3 minutes at a rate of 24 steps per minute. One step consists of four beats. For example; up with the left foot, up with the right foot, down with the left foot, down with the right foot. Keeping the speed constant and increasing the height of the bench can alter work rate.

The heart rate scores obtained at each minute are plotted on a graph. The line through the heart rate points is extrapolated to the estimated maximal heart rate of 170 beats per minute and a line dropped to the horizontal axis to estimate the VO₂ max. Step test however has limited number of stages that can be feasibly included for anyone’s bench height and individual fitness level. There is also the difficulty of taking measurements of blood pressure and heart rate during the testing phase (Corbin et al., 2002).
2.7.5 Field Tests

Field tests are usually maximal and determine the cardio respiratory fitness either by measuring how far an individual can run/walk in a given time or how fast one can run /walk at determined distances. Field tests rely on the observation that for one to run or walk over long distances, the heart must pump large volume of oxygen to the muscles. Howley and Franks (2007) observe that field tests correlate highly with the laboratory measures of VO\textsubscript{2} max and are preferred because they use natural activities of walking and running, they require very little equipment, are easy to administer and can test many subjects at the same time. However, they have the disadvantage of inability to monitor physiological responses of heart rate and blood pressure and also demand the subjects to be highly motivated to complete the test. The commonly used field tests include the following two, as well as the multistage shuttle run test that is used in this study and is also described in chapter three.

a) Cooper's 12-Minute/ 1.5 Mile Run Test

This is a maximal run test, easy to administer and requires only a measured level distance truck. The subjects are required to cover as great a distance as possible in 12 minutes either by running or walking or both. The greater the running/ walking speed, the more the oxygen uptake required. The distance covered is the final score for the subject. The test correlates highly with laboratory VO\textsubscript{2} max measures at r\textasciitilde0.90. The test is maximal and thus not recommended for older people at higher risk of ischemic heart disease. However, this test can be used to evaluate current cardio respiratory fitness without expensive equipment (Howley and Franks, 2007).
b) 1mile walk test

The test requires the subject to walk as fast as possible for 1 mile on a flat measured truck. The subject’s heart rate is measured at the end of the last lap. The time and heart rate required to cover the 1-mile distance reduce as an individual’s fitness improves. Heart rate is counted for 15 seconds immediately after the walk and then multiplied by four to get a 1-mile heart rate. This test has advantage over other field tests in that it allows use of heart rate to estimate VO$_2$ max (Baumgartner and Jackson, 1999).

2.8 Periodisation of Training

Training for competitive events during a sports season should be planned in such away that players reach their peak performance at the right time of the competition season. During the peak phase the training activities are aimed at challenging the physiological system while the valley phase allows the body to recover and adapt. In order to reap the benefits, players should be taken through the training programme gradually. This ensures that they are at their best form at the right time of the competition season. To achieve this, training should begin with emphasis on aerobic training whereby the volume of training activities is gradually increased. As the season progresses focus then is shifted to an emphasis on the intensity but with reduced volume since higher intensity exercises require more time for recovery. Periodisation in general enables the players to optimize performance while at the same time minimising the risk of overtraining (Corbin et al, 2002).

2.9 Significance of a High Aerobic Capacity to Rugby Players

Periodisation allows manipulation of repetition, resistance and exercise selection in such a way that players have a peak and valley phase during training programme. In order to improve performance, it is necessary to improve individual players’ maxi-
mal oxygen uptake. The purpose of aerobic training is to increase the ability of the oxygen transport system (cardiovascular system) so as to improve oxygen uptake, which in turn increases the oxygen supply to the cells of the active muscles. All individuals can make drastic improvements in VO₂ max with the right training stimulus. Furthermore, the effects of the aerobic training persist for as long as training continues (Hampson, 1998).

Reilly (1990) explains that, players in rugby union require good aerobic base to remain in the game for over 80 minutes. He further notes that a strategy for training in the game of rugby can be evolved from an analysis of the demands of the game. He is also of the idea that, apart from preparing players for intermittent sprinting with varying recovery periods between each bout, rugby coaches should plan for an endurance training that would enable the players to remain in play in the entire game duration without giving in to fatigue.

However, Anspaugh et al., (1991) caution that aerobic fitness developed in years of continuous training can be lost in a matter of months if training is interrupted or discontinued, hence the need for players to habitually engage in training not only during the competition season but also during the off season in order to maintain sufficient aerobic base. In a longitudinal study by Anspaugh et al., (1991), subjects suspended training for 84 days after 10 years of active participation. These subjects experienced significant decline in aerobic capacity after only 3 weeks of inactivity returning to pre-training levels in most fitness parameters by the end of the study. The only exception to complete reversal was the muscle capillary density and mitochondria enzymes that remained 50% higher than levels in the sedentary group.
The study further revealed that the effects of inactivity are variable and affect some systems more than others. This is because aerobic capacity is a product of integration of functional capacity of the lungs, circulatory and muscular system (Isaacs and Payne, 2002).

2.10 Aerobic Capacity Related to Age

Astrand and Rodahl (2003) have observed that athletes aged 20 to 30 years usually obtain the best performances in events demanding high \( \text{VO}_2 \text{max} \). They further assert that males usually reach the highest maximal oxygen uptake before ages 18 to 20 years mainly because at this age the young adult is regularly physically active especially where Physical Education is compulsory in school/college. After the oxygen uptake peak is reached, it can be maintained or increased for 10 years provided training is maintained. However, gradual decline in \( \text{VO}_2 \text{max} \) beyond age 20 is partly due to reduction in maximal heart rate and inactivity. Inactivity decreases the functional range of the oxygen transporting system due to reduced stroke volume. Age related decrease in peak heart rate occurs at approximately one beat per year after age 25. Tanner, (in Astrand and Rodahl, 2003) also caution that due to genetic make up, individuals at the same age may display variations in \( \text{VO}_2 \text{max} \) and the time it peaks. Therefore it is not unlikely to find older individuals with maximal aerobic power higher than that found in much younger individuals.

2.11 Relationship Between Positional Roles in Rugby and \( \text{VO}_2 \text{max} \)

Reilly (1990) has noted that each positional role in rugby has unique demands with type and frequency of training varying markedly with the level of play. Furthermore, rugby players cover varying distances during match play suggesting that players require varying aerobic capacities. Docherty et al (in Reilly 1990) for example have explained that, centers and props spend 85% of the game time in low intensity activ-
ity, 15% in intensive activity, 6% running, and 9% tackling, pushing and competing for the ball. They have also given the estimated distance covered by a player during a game of rugby as 4.8 to 9.6 km. They further observe that this distance, 37% is covered walking, 29% jogging and 37% sprinting. This therefore requires that a player should have good aerobic base to sustain the 80 minutes game time without giving in to fatigue.

Studies on aerobic capacity of rugby players in relation to positional roles have shown varying differences in aerobic capacities between forwards and backs. A study done using USA rugby club players during competitions by Reilly (1990) showed that the backs had VO$_2$ max of 59.5 ml/kg/min compared to 54.1 ml/kg/min observed in forwards. Reilly concluded that the higher VO$_2$ max among the backs is as a result of the greater work-rate demands of this position. Similarly, studies by Hazeldine and Homlyard (1993) using elite female rugby union players showed high VO$_2$ max among the backs, of namely 47.3 ml/kg/min compared to the forwards' 43.8 ml/kg/min. However, similar studies on Japanese inter-college competition players did not show significant differences between positional groups where 54.7 ml/kg/min was observed for the forwards, and 55.8 ml/kg/min for the backs (Reilly, 1990).

2.12 Studies on Aerobic Capacity and Team Sports

Most ball games involve activities of great intensities lasting a few seconds, interrupted by periods of rest or light activities. Therefore, most players especially those who participate in team sports, have lower maximal oxygen uptake than endurance athletes (Astrand and Rodahl, 2003). Training programmes should be designed in such a way that they would develop desirable fitness levels allied to sports skills so
that the individual and the team can achieve the long term goals for the season and the short term build up for the impending competition (Reilly, 1996).

Astrand and Rodahl’s 2003 study on elite soccer players for example, showed a maximal oxygen uptake significantly below the levels found in endurance athletes. Eleven Swedish elite soccer players in the study presented a mean aerobic capacity value of 56.5ml/kg/min. A similar study using fifty elite soccer players showed a mean aerobic capacity value of 58.6ml/kg/min.

Another study on Swedish elite ice hockey players by Astrand and Rodahl’s (2003) showed a mean aerobic capacity value of 65ml/kg/min. The high aerobic capacity of ice hockey players was attributed to the intense endurance training. Similar studies by Reilly and Secher (1990) on male field hockey players participating in Olympic games presented VO2 max values of between 48 and 65ml/kg/min. Similarly, a study on Australian male hockey team players showed a VO2 max value of 60 ml/kg/min (Reilly, 1990).

Astrand and Rodahl (2003) advanced the view that rugby players do not require the same level of aerobic endurance as is required in distance athletes who demand continuous long lasting effort or near maximal intensity. Reilly’s 1990 estimates of aerobic power for professional rugby league players have been in the range of 38.6 to 67.5ml/kg/min. His study found out that despite having contrasting match play activities, the physiological profiles of professional rugby league players are remarkably similar. This suggests that fitness training for professional rugby league is uniform for all players.
Studies done using international rugby union players on aerobic capacity by Reilly and Kirby (1993) revealed a significant increase in predicted VO$_2$ max for all the players in the study. The backs, however, recorded significantly higher predicted VO$_2$ max (51.0ml/kg/min) than the forwards (48.5ml/kg/min) at the beginning of the season but as the season progressed, the aerobic power between the backs and the forwards were not significantly different.

Kuhn (1993) conducted a comparative analysis of selected motor performance variables in American football, rugby union and soccer players. His study revealed that, there were differences between the three football codes with regards to constitutional factors (height and body mass), skin fold thickness, visual anticipation, absolute strength and aerobic capacity. His study also revealed that soccer players reached lactic threshold at a significantly higher speed than the rugby union players and American football players. He concluded that, this is due to the fact that soccer is a relatively continuous game requiring higher degree of aerobic power while rugby and American football are characterized by frequent stop and go activities.

Study by Gabbett (2000) on physiological status of amateur rugby league players compared to professional league players found out that the amateur rugby league players had low training status, with players devoting only 3 hours per week for team training and 30 minutes to individual training. The amateur rugby league players recorded 38.98 ml/kg/min. This compared with 5 to 7.5 hours of training by professional players. The aerobic fitness of the backs and forwards did not differ significantly, suggesting that position specific training did not occur and fitness training appears to be uniform for all players. The low fitness of amateur rugby players was
attributed to low playing intensity and inappropriate training stimulus. Gabbett (2000) concluded that the duration of the training stimulus employed by amateur league players was inadequate to induce significant peripheral and/ or central adaptations for improvements in VO$_2$ max. Alternatively, the low estimated VO$_2$ max suggested that the volume and intensity of training might differ between amateur and professional rugby league.

Wanjiku (2003) conducted a study on aerobic capacity levels of a selected soccer premier league teams and concluded that the teams that ranked high had also the highest VO$_2$ max levels. The study also indicated that the midfielders had the highest aerobic capacity and the goalkeepers recorded the lowest mean aerobic capacity.

Aerobic capacity assessment on Kenyatta University male soccer players by Njororai et al., (2003) showed an increase in aerobic capacity values by all players between pre-test and post-test measurements. These results also showed that aerobic capacity varied with positional role in the game of soccer. They concluded that conditioning for aerobic capacity is therefore a critical aspect of an athletes training programme and there is a need to departmentalize the training in order to ensure that every player develops an aerobic capacity specific to his role during a game.

A study by Malomsoki (1993) on physiological characteristics of football players in field conditions using an intermittent exercise protocol characteristic of the efforts applied in rugby found out that, players with great aerobic capacity reached their maximum steady state at a higher level than those with low aerobic capacity. He concluded that football players have good aerobic and anaerobic metabolic character-
istics and suggested that the results could also be applied to players participating in other ball game oriented sports.

Research on Kenya Cup rugby league players was conducted by Asembo (1992) to investigate whether Giessener soccer fitness test is applicable to players in other sports (rugby, hockey and soccer). The study showed that there was no significant difference in anthropometrical measures of age and height of the subjects but established a weak significant difference in the weight of the subjects. His study however did not assess the aerobic capacity status of the players.

2.13 Summary

Several studies have been carried out on aerobic capacity of athletes in different sports. Aerobic capacities on soccer players for example have been carried out by Astrand and Rodahl (1986), Gabbett (2000), Malomski (1993), Reilly (1990), Kuhn (1993), Njororai et al., 2003, and by Wanjiku (2003). Similar studies on professional rugby players have been carried out by Reilly (1990), Reilly et al (1993), and Hazeldine and Holmyard (1993). Asembo (1992) likewise carried out a study on applicability of Giessener fitness test on rugby, hockey and soccer players.

Many of these aforementioned studies on aerobic capacity of players have been carried out in developed countries. Apart from the aerobic capacity on Kenya soccer premier league players study by Wanjiku (2003), no such study have been carried out to investigate aerobic capacity of players of rugby players or any other sport in Kenya. This study therefore, investigated the aerobic capacity status of Kenyan male rugby players participating in 2005 Kenya Cup League. The players’ aerobic capacity according to age was also investigated. Similarly, players’ aerobic capacity in relation to team ranking and positional roles was also investigated.
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 that were used in the study.

3.2 Research Design
Quasi-experimental research design using pre-test and post-test data collection procedure was used. This design was used because the randomly selected teams were being studied as intact groups whereby players were tested in their respective teams during the competitive season. For this reason it was not possible to use any of the teams participating in the Kenya cup league as a control group since each team preferred to follow their own tailored training programme. A pre-test was conducted using the progressive multistage shuttle run test to determine the individual players’ aerobic capacity at the beginning of the league competition. This was followed with a post-test after eight weeks of training and competition to establish whether there were any changes in aerobic capacity. Maughan and Gleeson (2004) explain that most physiological responses occur within a period of 6 to 8 weeks of training.

3.3 Variables
This study included the following variables:

a) Aerobic Capacity/Maximum Oxygen Uptake (VO₂ max)
This was the dependent variable on which every subject was tested twice. A pre-test was done at the beginning of the league and a post-test after eight weeks of training and competition. Relevant training programme elicits changes in VO₂ max. Players VO₂ max was predicted using National Coaching Foundation Manual Scoring Crite-
ria shown in appendix A. This study focused on the VO₂ max because although other parameters of performance are important, the background against which skills can be translated into good performance is through maintenance of endurance fitness.

b) Age

This was an independent variable and represented individual subject’s date of birth. Subjects’ ages were grouped for this study as follows, ages 18-20, 21-25, and above 26 years. According to Astrand and Rohdal (2003), Individuals’ aerobic capacity/maximum oxygen uptake (VO₂ max) varies with age, peaking from age 18 to 20, stabilises at age 21 to 25 and begins to decline gradually after 25 years.

c) Field Position

This refers to the role the individual participant play during a game of rugby as used in this study. A participant is either in a back or a forward position. The rugby union game comprises of 8 forwards and 7 backs. The aerobic capacity of forwards and backs were estimated using the National Coaching Foundation Manual Scoring Criteria shown in appendix A. Field position was an independent variable in this study.

d) Rank

Rank was a dependent variable in this study and it refers to the position a team obtained according to its performance in the Kenya Cup League competition 2004. Players used in this study were drawn from the top, middle and bottom ranked teams in the 2004 Kenya Cup League shown in appendix B. This study also ranked teams according to the mean VO₂ max attained after eight weeks of training and competition.
3.4 Location of the Study

The study was carried out in Nairobi city and Nakuru town. This was because after stratified random sampling was done, the teams sampled happened to be located in the two mentioned areas.

3.5 Target Population

The target population comprised of players in seven rugby teams that participated in Kenya Cup League 2004 competition as shown in appendix B. Six of these teams were based in Nairobi and one in Nakuru. Each team had registered thirty (30) players for the league. The target population therefore comprised of 210 players.

3.6 Sampling Technique

According to Gay (1996) a sample size of 10% of the total population is adequate in a large population and a sample of 20% of the total population is acceptable in a small population as is the case in quasi-experimental designs such as this one. A stratified random sampling procedure was used after putting the seven teams in three strata according to the finishing rank or position in the 2004 league shown in appendix B. From each stratum one team was randomly selected. This enabled the researcher to get a sample from the top, middle and bottom ranked teams. The players who therefore participated in this study were from Impala RFC, Harlequins RFC, and Nakuru RFC.

3.7 Sample Size

Each of the three teams randomly selected had thirty- (30) registered players. The sample size therefore comprised of 90 players. This represented 35.7% of the total target population.
3.8 Instrumentation

A pre-test post-test method was used to obtain the participants VO$_2$ max data using the multistage shuttle run test. The testing procedure outlined by the National Coaching Foundation Manual of 1998 was used. Multistage shuttle run test is a convenient field test for rugby since it is a field activity (Reilly, 1996). The test produces reliable results and has been widely used to assess the endurance capacities of all types of sports participants as well as by individuals interested in their own fitness (Brewer et al., 1998). The multistage fitness test results correlates highly with laboratory measures of VO$_2$ max at $r = 0.92$ (Brewer et al., 1998). Moreover, it is an easy test to administer and a large group of players can be tested at the same time. Instructions are also few and easy to follow. Requirements for the test included a level running surface of exactly 20 meters, a 30m tape measure, pre-recorded audiotape or, an audio tape player, 30 markers, some VO$_2$ max assessment protocol sheets and three assistants. The procedure of conducting multistage shuttle run test is as shown in appendix C. The test was administered during the evening training sessions between 5.30pm and 6.30pm.

The test began by players running between two lines marked 20 meters apart. Players aimed at keeping up with the bleeps from a pre-recorded audiotape. The bleeps started off slowly and gradually increased to a faster pace. This required individual player to keep up with the speed and either voluntarily withdrew or were removed from the test when one could not keep up with the speed of the bleeps. The level at which the player withdrew or was removed, and the number of the shuttles covered by the time of withdrawal, were read against the published and validated predicted VO$_2$ max scores shown in appendix A. Each player was tested a second time after
following gentle stretching activities before the test commenced: Hamstring stretcher, shin stretcher, hip and thigh stretcher, alternate leg lunge, ankle rotation, knee hugs, sideways stretch and knee flex and ankle extension. This was meant to raise the body temperature and loosen up muscles and joints so as to reduce risk of injury as well as enhancement of performance. Raised body temperature reduces blood viscosity thus enhancing oxygen delivery to the muscles. Warmed up muscles contract without risk of injury or muscle cramps.

The players in each team were divided into three groups and then each group took the test in turns. The researcher and the assistants assigned themselves three to four subjects each for the purpose of recording. The players were verbally motivated during the test in order to sustain their interest. This is because the reliability of the multistage shuttle run test not only depends on how strict the test is conducted but also on individual’s level of motivation to perform the test. Players who waited for their turn to take the test or who had already been tested also encouraged their teammates. Test observations made at the beginning of the competition season and at post-test after eight weeks were recorded in the protocol sheets shown in appendix E. Age, as given by individual players, was also entered in the same protocol sheet.

Some of the players did not avail themselves for a post-test after eight weeks. This reduced the sample size to 69, down from 90 players. The numbers of the players available for both pre-test and post-test for each team were therefore as follows, Impala, 26; Harlequins, 21; and Nakuru RFC, 22. Since the objective of the test was to compare two measurements of VO₂ max from each player both at the start of competitions and then after eight weeks, the players who dropped out could not have been
replaced with others from their teams. Thus the overall sample size used in pre-test and post-test was 69 players which constituted 32.9% of the population which according to Gay (1996) was statistically significant.

3.11 Logistical and Ethical Considerations

The researcher acquired official permit to conduct research. A copy of letter used is shown in appendix F. The exhaustive nature of the multi-stage shuttle run test was explained to the players and their coaches before data collection commenced. If anyone was sick or injured they could not have been subjected to the test. Warm-up exercises always preceded the test in order to minimize risks of injuries and also to ensure best performance. The test was conducted outdoors, on safe, level ground, during the teams’ evening training sessions. Confidentiality on the test results was assured to all participating players and their respective coaches.
CHAPTER FOUR
DATA ANALYSES, PRESENTATION AND DISCUSSION

4.1 Introduction

This chapter presents data analyses, interpretation and discussion of the results.

4.2 Data Analyses Methods and Presentation

The data obtained were analyzed using Statistical Package for Social Sciences (SPSS). The aerobic capacity values of pre- and post-test measurements were analyzed descriptively. The mean as an indicator of the average score was used to interpret the overall performance of subjects in each team. One-way analysis of variance and t-test were used to test the research hypotheses at 0.05 level of significance. Tukey HSD post hoc test was conducted to establish the magnitude of difference for the team ranking following significant F-ratio. The data were then presented using charts and tables.

4.3 Demographic Factors of Players

The Kenya Cup rugby league team comprised fifteen players. Of these, eight were forwards and seven were back players. The number of players who participated in this study by their positions is shown in figure 4.1. Distribution of players by age is also shown in figure 4.2.
Figure 4.1 Distribution of Players by Field Positions

Key:
b----backs
f-----forwards

Figure 4.1 indicates the percentage of players who participated in this study in both the forward and back positions. The figure shows that backs comprised of 51% of the population while the forwards represented 49%. This indicates that the two playing positions were well represented.
Figure 4.2 Distribution of Players by Age

Figure 4.2 indicates that majority of players were between ages 19 and 23 years. It also shows that there were only a few players aged 26 years and above. This reflects KRFU's (2004) observation that majority of rugby players quit the game at age 24 after graduating from college. Most Kenyan rugby players are either in college or waiting to join college at ages 19 and 20 hence the highest percentage representative of this age shown in figure 4.2.

4.4 Aerobic Capacity Values by Teams

The pretest and posttest aerobic capacity values of players of the teams that were studied are shown in tables 4.2, 4.3, and 4.4.
Table 4.1: Impala RFC Players’ Pre-test and Post-test Aerobic Capacity Values

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Field position</th>
<th>Pre-test</th>
<th>Post-test</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Back</td>
<td>47.4</td>
<td>44.5</td>
<td>-2.9</td>
</tr>
<tr>
<td>2</td>
<td>Back</td>
<td>47.4</td>
<td>46.8</td>
<td>-0.6</td>
</tr>
<tr>
<td>3</td>
<td>Back</td>
<td>45.2</td>
<td>48.0</td>
<td>2.8</td>
</tr>
<tr>
<td>4</td>
<td>Back</td>
<td>32.9</td>
<td>34.3</td>
<td>1.4</td>
</tr>
<tr>
<td>5</td>
<td>Back</td>
<td>45.8</td>
<td>48.0</td>
<td>2.2</td>
</tr>
<tr>
<td>6</td>
<td>Back</td>
<td>47.4</td>
<td>40.5</td>
<td>-6.9</td>
</tr>
<tr>
<td>7</td>
<td>Back</td>
<td>46.8</td>
<td>48.0</td>
<td>1.2</td>
</tr>
<tr>
<td>8</td>
<td>Back</td>
<td>47.4</td>
<td>48.7</td>
<td>1.3</td>
</tr>
<tr>
<td>9</td>
<td>Back</td>
<td>47.4</td>
<td>43.3</td>
<td>-4.1</td>
</tr>
<tr>
<td>10</td>
<td>Back</td>
<td>47.4</td>
<td>41.1</td>
<td>-6.3</td>
</tr>
<tr>
<td>11</td>
<td>Back</td>
<td>45.2</td>
<td>41.1</td>
<td>-4.1</td>
</tr>
<tr>
<td>12</td>
<td>Back</td>
<td>47.4</td>
<td>41.1</td>
<td>-6.3</td>
</tr>
<tr>
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<td>Back</td>
<td>47.4</td>
<td>43.3</td>
<td>-4.1</td>
</tr>
<tr>
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</tr>
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<td>1.6</td>
</tr>
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<td>Forward</td>
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<tr>
<td>Mean</td>
<td></td>
<td>44.79</td>
<td>44.52</td>
<td>-0.28</td>
</tr>
</tbody>
</table>

Table 4.1 shows aerobic capacity values for the Impala RFC players. The highest aerobic capacity value recorded at pre-test was 49.3 ml/kg/min and the lowest was 32.9 ml/kg/min. After eight weeks of training and competition, the highest post-test aerobic capacity value for the team was 52.5 ml/kg/min and the lowest was 34.3 ml/kg/min. The highest increase between pre-test and posttest was 5.1 ml/kg/min.
while the greatest decline of 6.9 ml/kg/min was recorded. The overall mean for the team at pre-test was 44.79 ml/kg/min and 44.52 ml/kg/min at post-test. This indicated a decline of 0.27 ml/kg/min. The table also shows that the same player recorded the lowest aerobic capacity values both at pretest (32.9 ml/kg/min) and post-test (34.3 ml/kg/min). The differences in VO2 max among the club players could be attributed to varying levels of involvement during training and competitions. Training intensity, duration and frequency determine the rate of improvement in VO2 max as noted by Maughan and Gleeson (2004).

Table 4.2 shows the aerobic capacity values of Harlequins RFC players at pre-test and post-test. The highest VO2 max value at pre-test was 48.0 ml/kg/min and the lowest was 33.6 ml/kg/min. At post-test, the highest VO2 max value recorded was 45.8 ml/kg/min and the lowest was 32.9 ml/kg/min. The highest increase between pre-test and post-test were 6.2 ml/kg/min and the greatest decline of 2.7 ml/kg/min were noted. The mean VO2 max value for the team at pre-test was 39.33 ml/kg/min and at posttest the team recorded a mean of 40.20 ml/kg/min. This indicated a slight increase of 0.87 ml/kg in club players’ VO2 max. This might be as a result of different levels of physical involvement during training and competitions (Maughan and Gleeson, 2004). The intensity of activity varies with individuals, such that what produces improvement in VO2 max in one person could elicit little or no changes in another. A high standard of training as advised by Reilly and Secher (1990) is essential for rugby players in order for sports potential to be realized.
Table 4.2: Harlequins RFC Players’ Pre and Post-test Aerobic Capacity Values

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Field position</th>
<th>Pre test</th>
<th>Post test</th>
<th>Difference</th>
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</tbody>
</table>

Table 4.3 shows the Nakuru RFC players’ VO\textsubscript{2} max values recorded both at pre-test and post-test. The highest VO\textsubscript{2} max value at pre-test was 53.7ml/kg/min and the lowest was 26.8ml/kg/min. The highest value at post-test after eight weeks of training and competitions was 50.2ml/kg/min and the lowest was 27.6ml/kg/min. Table 4.3 also shows the highest VO\textsubscript{2} max increase between pre-test and post-test as 7.4ml/kg/min and a greatest decline of 15.5ml/kg/min. The mean VO\textsubscript{2} max value for the team is shown to have declined from 43.44ml/kg/min to 42.50ml/kg/min, a decline of 0.94ml/kg/min. These differences in VO\textsubscript{2} max among the players may be due
to varying levels of physical exertion during training and competitions and the fact that some players may be part of the national team that plays international competitions that are more intensive than the local leagues.

**Table 4.3: Nakuru RFC Players’ Pre and Post-test Aerobic Capacity Values**

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Field position</th>
<th>Pre-test</th>
<th>Post-test</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Back</td>
<td>38.5</td>
<td>45.9</td>
<td>7.4</td>
</tr>
<tr>
<td>2</td>
<td>Back</td>
<td>53.7</td>
<td>46.8</td>
<td>-6.9</td>
</tr>
<tr>
<td>3</td>
<td>Back</td>
<td>48.0</td>
<td>50.2</td>
<td>2.2</td>
</tr>
<tr>
<td>4</td>
<td>Back</td>
<td>48.0</td>
<td>43.9</td>
<td>-4.1</td>
</tr>
<tr>
<td>5</td>
<td>Back</td>
<td>48.0</td>
<td>48.7</td>
<td>0.7</td>
</tr>
<tr>
<td>6</td>
<td>Back</td>
<td>46.3</td>
<td>43.3</td>
<td>-3.2</td>
</tr>
<tr>
<td>7</td>
<td>Back</td>
<td>53.1</td>
<td>43.9</td>
<td>-9.2</td>
</tr>
<tr>
<td>8</td>
<td>Back</td>
<td>43.9</td>
<td>48.7</td>
<td>4.8</td>
</tr>
<tr>
<td>9</td>
<td>Back</td>
<td>50.2</td>
<td>43.9</td>
<td>-6.3</td>
</tr>
<tr>
<td>10</td>
<td>Back</td>
<td>45.2</td>
<td>48.0</td>
<td>2.8</td>
</tr>
<tr>
<td>11</td>
<td>Back</td>
<td>39.9</td>
<td>41.1</td>
<td>1.2</td>
</tr>
<tr>
<td>12</td>
<td>Forward</td>
<td>26.8</td>
<td>27.6</td>
<td>0.8</td>
</tr>
<tr>
<td>13</td>
<td>Forward</td>
<td>36.4</td>
<td>41.1</td>
<td>4.7</td>
</tr>
<tr>
<td>14</td>
<td>Forward</td>
<td>37.8</td>
<td>39.9</td>
<td>2.1</td>
</tr>
<tr>
<td>15</td>
<td>Forward</td>
<td>41.1</td>
<td>39.9</td>
<td>-1.2</td>
</tr>
<tr>
<td>16</td>
<td>Forward</td>
<td>41.8</td>
<td>38.5</td>
<td>-3.3</td>
</tr>
<tr>
<td>17</td>
<td>Forward</td>
<td>51.9</td>
<td>36.4</td>
<td>-15.5</td>
</tr>
<tr>
<td>18</td>
<td>Forward</td>
<td>39.2</td>
<td>39.9</td>
<td>0.7</td>
</tr>
<tr>
<td>19</td>
<td>Forward</td>
<td>40.5</td>
<td>45.2</td>
<td>4.7</td>
</tr>
<tr>
<td>20</td>
<td>Forward</td>
<td>41.1</td>
<td>39.2</td>
<td>-1.9</td>
</tr>
<tr>
<td>21</td>
<td>Forward</td>
<td>43.3</td>
<td>43.9</td>
<td>0.6</td>
</tr>
<tr>
<td>22</td>
<td>Forward</td>
<td>41.8</td>
<td>39.9</td>
<td>-1.9</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td><strong>956.7</strong></td>
<td><strong>935.9</strong></td>
<td><strong>-20.8</strong></td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td><strong>43.44</strong></td>
<td><strong>42.5</strong></td>
<td><strong>-0.95</strong></td>
</tr>
</tbody>
</table>

Table 4.4 shows a summary of the teams’ aerobic capacity values. It is indicated that the backs for the three teams recorded higher VO$_2$ max both at pre and post-test than the forwards. The table also shows that, Impala RFC recorded the highest VO$_2$ max both at pre-test (44.8ml/kg/min) and post-test (44.5ml/kg/min). Nakuru RFC followed with 42.7ml/kg/min at pre-test and 42.2ml/kg/min at post-test. Harlequins
RFC had the lowest \( \text{VO}_2 \text{max} \) both at pre-test (39.3ml/kg/min) and post-test (40.2ml/kg/min).

Table 4.4 Summary of Pre and Post-test Teams’ \( \text{VO}_2 \text{max} \) Values

<table>
<thead>
<tr>
<th>Rank</th>
<th>Team</th>
<th>Player’s position</th>
<th>Pre-test mean</th>
<th>Overall pre-test mean</th>
<th>Player’s position</th>
<th>Post-test mean</th>
<th>Overall post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Impala</td>
<td>Forward</td>
<td>43.6</td>
<td>44.8</td>
<td>Forwards</td>
<td>44.4</td>
<td>44.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Backs</td>
<td>46.9</td>
<td></td>
<td>Backs</td>
<td>44.8</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Harlequins</td>
<td>Forwards</td>
<td>39.0</td>
<td>39.3</td>
<td>Forwards</td>
<td>39.3</td>
<td>40.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Backs</td>
<td>39.6</td>
<td></td>
<td>Backs</td>
<td>41.2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Nakuru</td>
<td>Forwards</td>
<td>40.2</td>
<td>43.4</td>
<td>Forwards</td>
<td>39.2</td>
<td>42.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Backs</td>
<td>46.8</td>
<td></td>
<td>Backs</td>
<td>45.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Overall mean</td>
<td></td>
<td>42.5</td>
<td></td>
<td></td>
<td></td>
<td>42.3</td>
</tr>
</tbody>
</table>

As shown in table 4.4, both Impala and Nakuru RFC players had their aerobic capacity decline between pre and post-test from 44.8 to 44.5ml/kg/min and 43.4 to 42.2ml/kg/min respectively. Harlequins RFC on the other hand recorded a slight improvement in \( \text{VO}_2 \text{max} \) between pre and post-test from 39.3 to 40.2ml/kg/min. It is also evident from the table that overall rugby players’ aerobic capacity declined from 42.7ml/kg/min at pre-test to 42.5ml/kg min at post test, by 0.2ml/kg/min.

Despite the teams’ differences in \( \text{VO}_2 \text{max} \) values, the variations are small and can be attributed to sampling error and some individual subjects recording extreme \( \text{VO}_2 \text{max} \) scores thus affecting the overall average score for the team. The minimal variations also indicate that players in the three clubs may have been exposed to almost similar training programmes. This is in agreement with Reilly’s (1990) observation that despite contrasting match play, rugby players’ physiological profiles are remarkably similar suggesting that fitness training was uniform. The variations in \( \text{VO}_2 \text{max} \) amongst rugby players in the three clubs are in agreement with Fahey et al.,
sentiments that people respond differently in similar training programmes because intensity of training may be right for one person and little effect to another. Similarly research findings by Foss and Keteyian (1998) and Astrand and Rodahl (2003) attribute individual VO$_2$ max differences to individuals’ genetic make-up but they explain that attaining ones’ aerobic potential can only occur through aerobic endurance training using appropriate training regimen.

4.5: Hypotheses Testing

The study set out to test the following hypotheses:

1. There was no significant difference in aerobic capacity of rugby players between pre-test and post-test.
2. There was no significant difference in aerobic capacity amongst players of different age groups.
3. There was no significant difference in aerobic capacity amongst the top, middle and the bottom ranked team.
4. There was no significant difference in aerobic capacity between the forwards and the backs.

4.5.1 Aerobic Capacity of Rugby Players Between Pre-test and Post-test

To test whether there were any differences in aerobic capacity among rugby players between pre-test and post-test, a t-test was conducted and yielded the following results shown in table 4.5.

Table 4.5: t-test on Players’ VO$_2$ max Between Pre-test and Post-test

<table>
<thead>
<tr>
<th>Source</th>
<th>Number</th>
<th>Mean</th>
<th>SD</th>
<th>t-value</th>
<th>DF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-test</td>
<td>69</td>
<td>43.1478</td>
<td>6.92</td>
<td>0.88</td>
<td>68</td>
</tr>
<tr>
<td>Post-test</td>
<td>69</td>
<td>42.5971</td>
<td>4.83</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Critical t=2.0 p>0.05
Table 4.5 indicates that there were no significant differences in players’ aerobic capacity between pre-test and post-test. This is because the calculated t-value of 0.88 was less than the critical value of 2.0 at 0.05 alpha level. Therefore the hypothesis that there were no significant difference in rugby players’ aerobic capacity between pre-test and post-test was accepted. These results indicate that there were almost equal levels of physical involvement by rugby players during training. This also suggests that players undertook almost similar training regimen in their respective clubs.

It is noted in table 4.4 that a difference of 0.2ml/kg/min (42.5-42.3ml/kg/min) was obtained between pre-test and post-test which is a slight decline in aerobic capacity. However, incorporating endurance activities in the training programme during the competitive season can prevent decline in endurance fitness.

These results were also an indication that players were not spending sufficient time in training in terms of frequency, intensity and duration recommended by Maughan and Gleeson (2004), Corbin et al., (2002) and Watson, (1995). This was further supported by the observations by KRFC (2004) that Kenyan rugby players never turn up for training as a complete squad mainly because most of them are college students while others are on fulltime employment. Reilly (1996) also highlights that designing and conducting effective coaching sessions is not possible when players are not consistent in turning out for training. He explains that consistency allows the coach to assign players meaningful and purposeful roles and ensures that they practise skills and tactics they employ in their respective field positions during the match. Inconsistency in training leads to a decline or no improvement in aerobic capacity and poor skill performance. The problem of players’ unavailability for training was also im-
plied by the number of the subjects who never availed themselves for the post-test after eight weeks of training and league competition.

According to Watson (1995), aerobic capacity only improves when frequency of training is 3 to 5 days per week yet KRFU (2004) states the Kenya Cup Rugby Union players train only 2 days in a week with each training session lasting two hours. Individual players who recorded high aerobic capacity may be those who make up the National squad that participates in the series of International Rugby Board tournaments that runs concurrently with the Kenya Cup League. Their participation in such high-level competitions means they are more physiologically stressed resulting in improved VO₂ max.

As observed by Maughan and Gleeson (2004) duration, frequency and intensity of training are important features that should not be ignored if any improvement in aerobic capacity is to be experienced. These factors may have been overlooked by the coaches and players and could have led to a decline or very little improvement in VO₂ max. Physiological benefits such as myoglobin content, oxidative enzymes and muscle capillary density are the basis against which VO₂ max is dependent. These are also attained when intensity, frequency and duration of training are at suitable levels as noted by Fahey et al., (2001). Njororai et al., (2003) have equally emphasized the importance of conditioning for aerobic capacity as a critical aspect of an athletes’ training programme if at all the performance potential of an athlete is to be realized.
Table 4.6: Summary of VO$_2$ max by Players’ Age

<table>
<thead>
<tr>
<th>Age group</th>
<th>Number of players</th>
<th>Pre-test VO$_2$ max (ml/kg/min)</th>
<th>Post-test VO$_2$ max (ml/kg/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-20 yrs</td>
<td>28</td>
<td>43.16</td>
<td>43.42</td>
</tr>
<tr>
<td>21-25 yrs</td>
<td>33</td>
<td>42.72</td>
<td>42.07</td>
</tr>
<tr>
<td>Above 26 yrs</td>
<td>8</td>
<td>40.49</td>
<td>41.53</td>
</tr>
<tr>
<td>Total</td>
<td>69</td>
<td>42.64</td>
<td>42.47</td>
</tr>
</tbody>
</table>

Table 4.6 shows the mean VO$_2$ max values for players in different ages groups both at pre-test and post-test. It can be observed that the older players above 26 years had the lowest VO$_2$ max. However, VO$_2$ max for the three age groups of players were almost the same at the start of the league and after eight weeks of training and competition. This may be attributed to the fact that players may have started the league competition at almost same level of aerobic fitness and they may have also adopted similar training activities in their respective teams. Kenya Cup league players also compete under almost similar conditions since the league is conducted on home and away basis as noted by Mundia (2004).

4.5.2 Aerobic Capacity Amongst Rugby Players of Different Age Groups

Analysis of variance was conducted to establish whether there was significant difference in aerobic capacity amongst players of ages 18-20, 21-25 and those above 26 years. The results were as shown on table 4.7.
Table 4.7: ANOVA of Players’ Pretest and Posttest VO\textsubscript{2}\text{max} by Age Groups

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>48.524</td>
<td>2</td>
<td>24.262</td>
<td>0.80</td>
<td>.455</td>
</tr>
<tr>
<td>Within Groups</td>
<td>2010.108</td>
<td>66</td>
<td>30.456</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2058.632</td>
<td>68</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posttest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>89.853</td>
<td>2</td>
<td>44.927</td>
<td>1.98</td>
<td>.146</td>
</tr>
<tr>
<td>Within Groups</td>
<td>1498.777</td>
<td>66</td>
<td>22.709</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1588.630</td>
<td>68</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Critical F=3.14; p>0.05

The calculated F ratio of 0.80 at pre-test and 1.98 at posttest were less than 3.15 critical of F at 0.05 significance level. These findings therefore indicate that there were no significant differences in aerobic capacity amongst players of different age groups between pretest and posttest. Therefore the hypothesis that there were no significant different in aerobic capacity among players of different age groups participating in the Kenya Cup League 2005 season was accepted.

Lack of difference in VO\textsubscript{2}\text{max} between different age groups can be attributed to two facts. First, the rugby players may have entered the competitive season at almost the same level of fitness. The second fact is that they were also not consistent in training. According to Astrand and Rodahl (2003) inconsistency in training as is the case with Kenyan rugby players usually results in low aerobic capacity of an individual at any age. Training programmes used by rugby players may not have elicited stimulus for improvement of aerobic capacity. Since there is tendency to factor in skill and tactical practices during competitive season, players usually ignore the physical condi-
tioning aspect of the practice as individuals and as a team. The emphasis on skill related practice does not allow players to develop endurance, yet Foss and Keteyian (1998) and Faheh et al. (2001) have explained that an individual’s aerobic potential can only be reached through appropriate aerobic endurance training. Gradual decline in VO$_2$ max by players above 20 years of age as observed by Astrand and Rodahl (2003) could have been due to reduction in maximal heart rate and inactivity where the latter decreases the functional range of oxygen transport system.

Kenyan rugby players are far much on the lower end of the professional rugby players’ aerobic values as given by Reilly (1990) which range from 38.6 to 67.5ml/kg/min. Similarly, the players’ VO$_2$ max is low compared to international male and female rugby players as reported by Hazeldine and Holmyard (1993) and Reilly (1990). This could have been as a result of not having rugby as a professional sport to allow them spend sufficient time in training.

4.5.3 Aerobic Capacity Among Impala, Harlequins and Nakuru RFC

To establish whether there were significant differences in aerobic capacity of players among Impala, Harlequins and Nakuru RFC, one-way analysis of variance was conducted. The results are shown in table 4.8. The calculated F ratio of 7.23 at pretest and 4.97 at posttest as shown in table 4.8 indicates that there were significant differences in aerobic capacity among the three clubs both at the beginning of the competition and after eight weeks of training and competitions. This is because the two F ratios were greater than the critical value of 3.14 at 0.05 alpha level. Tukey HSD post hoc test revealed that the differences were statistically significant as indicated in table 4.9. Therefore, the hypothesis stating that there were no significant
difference in aerobic capacity among the top, middle and the bottom ranked team was rejected.

**Table 4.8: ANOVA Summary of Pre and Post VO$_2$ max by Rugby Clubs**

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>VO$_2$ pre</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>367.157</td>
<td>2</td>
<td>183.578</td>
<td>7.23*</td>
<td>.001</td>
</tr>
<tr>
<td>Within Groups</td>
<td>1676.169</td>
<td>66</td>
<td>25.397</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2043.326</td>
<td>68</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VO$_2$ post</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>207.937</td>
<td>2</td>
<td>103.969</td>
<td>4.97*</td>
<td>.010</td>
</tr>
<tr>
<td>Within Groups</td>
<td>1380.693</td>
<td>66</td>
<td>20.920</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1588.630</td>
<td>68</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Critical F=3.14; p>0.05

The differences suggest that teams started the league at varying levels of fitness with Impala and Nakuru players at a superior aerobic fitness than Harlequin players. It is to be noted however that, the teams aerobic fitness had declined after eight weeks of competitions as indicated by the F ratio of 4.97 at posttest compared to 7.23 at pre-test. The decline may be attributed to the fact that players had may hours of competitions as indicated by KRFU (2004) and the fact that same players are fielded for competitions due to a small player base as explained by Mundia (2004). This does not give players enough time to recover before the next match. Therefore maintenance of good aerobic base is compromised. Decline of aerobic fitness at posttest may also be accounted for by the fact that rugby players spend only 2 hours per week on training whereby their frequency in training is described by Mundia (2004) as inconsistent. Duration, intensity and frequency as noted by Maughan (2004) are among the most important factors that determine improvement of an individual’s VO$_2$ max.
Table 4.9: Tukey HSD for Teams’ Pretest Differences

<table>
<thead>
<tr>
<th></th>
<th>Impala</th>
<th>Harlequins</th>
<th>Nakuru</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impala</td>
<td></td>
<td>5.47*</td>
<td>1.31</td>
</tr>
<tr>
<td>Harlequins</td>
<td>-5.47*</td>
<td></td>
<td>-4.16*</td>
</tr>
<tr>
<td>Nakuru</td>
<td>-1.31</td>
<td>4.16*</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.9 indicates that mean VO₂ max differences occurred between Impala and Harlequins (5.47*) and between Nakuru and Harlequins (4.16*). The differences are an indication that some teams may have used superior training programmes in terms of intensity. Differences may also have been due to extreme VO₂ max values recorded by some individual players both at pretest and posttest. Extreme high or low scores in the distribution cause the mean as a measure of central tendency to be pulled towards an outlier or extreme score (Mugenda, 2003). As noted from table 4.1, the highest VO₂ max was 52.5ml/kg/min and lowest was 34.3ml/kg/min at posttest. The same can be observed in table 4.2 where the highest score of 45.8 compares with the lowest score of 29.5ml/kg/min. Some of the players also participate in international Rugby Board series of competitions and therefore are likely to be better conditioned thus may have recorded high aerobic capacity than those players who only participate in the Kenya Cup league and other local tournaments. Their participation in such high level competitions means that they are more physiologically stressed resulting in improved VO₂ max.

Table 4.10: Tukey HSD for Teams’ Posttest Differences

<table>
<thead>
<tr>
<th></th>
<th>Impala</th>
<th>Harlequins</th>
<th>Nakuru</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impala</td>
<td></td>
<td>4.23*</td>
<td>1.97</td>
</tr>
<tr>
<td>Harlequins</td>
<td>-4.23*</td>
<td></td>
<td>-2.26</td>
</tr>
<tr>
<td>Nakuru</td>
<td>1.97</td>
<td>2.26</td>
<td></td>
</tr>
</tbody>
</table>
Table 4.10 indicates significant mean differences in aerobic capacity between impala and Harlequins at posttest (4.23*) whereas the differences between Harlequins and Nakuru were not significantly different. The results were also an indication that the training programmes used by the three teams varied, whereby teams such as Impala and Nakuru may have used training activities that elicited improvement in peripheral and central physiological adaptation. Although the teams mean aerobic capacity values are within Reilly’s (1990) range of estimated aerobic capacities for the professional league players (36.8 to 67.5 ml/kg/min), they are on the lower end of the spectrum.

The fact that the three teams’ aerobic capacities declined at posttest agrees with observation by KRFU (2004) that Kenyan rugby players do not spend enough time training. The union has pointed out that players only train two (2) days in a week with each training session lasting only two (2) hours. Furthermore, players do not report for training regularly during the two days. The low aerobic capacity status at posttest was also an indication of low motivation among players as noted by Punter (2005). Players with low motivation are not committed to training. Reilly (1996) is in support of the view that players who are not motivated do not carry out activities with energy and enthusiasm and also do not adhere to the activity with high level of commitment. Interest and motivation among other factors are as important as motor skills in achieving performance. This applies in case of long-term training for a competition as well as during the actual competition. A professional game, as observed by Reilly (1996) is a job that provides a living that is extremely lucrative and this highly motivates the player. The fact that the game of rugby in Kenya is not played on professional basis means that players do not spend enough time in training while
some players fail to turn up for training as they are to attend college while others are in fulltime employment. This could therefore have led to decline in teams’ aerobic capacity between pre-test and post-test.

The competition oriented training adopted by rugby players participating in Kenya Rugby Cup league during the in-season emphasizes more on tactics and skills at the expense of general fitness training as indicated by the activities shown in appendix G. This could have led to the low aerobic capacity levels recorded by players at posttest. Low aerobic capacity amongst players has also been reported by Gabbett (2000) during the in-season as a result of competition oriented training similar to the one adopted by the Kenya Cup league players. The competition-oriented training predisposes players to injuries leading to a period of temporary inactivity. Garraway (1993) has also noted that rugby is a highly contact game and injuries are frequent occurrences that produce periods of temporary disability. Inactivity due to injury as reported by Anspaugh et al., (1991) lowers athletes’ aerobic capacity.

4.5.4 Aerobic Capacity of Rugby Players by Positions

The mean aerobic capacity for the position of players was calculated and the results are shown on table 4.11. The table indicates that the backs had higher aerobic capacity value (43.9 ml/kg/min) than the forwards (40.9 ml/kg/min).

| Table 4.11: Mean \( \text{Vo}_2\text{max} \) Summary for the Rugby Playing Positions |
|-----------------|-----------------|-----------------|
| Team            | Forwards        | Backs           |
| Impala          | 44.4            | 44.8            |
| Harlequins      | 39.3            | 41.2            |
| Nakuru          | 39.2            | 45.9            |
| Total mean      | 40.9            | 43.9            |
To establish whether there were significant differences in aerobic capacity between forwards and backs, analysis of variance was conducted and yielded the following results on table 4.12.

**Table 4.12: ANOVA Summary of Pre and Post VO\(_2\) max on Players’ Positions**

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Critical F=3.99 \(p>0.05\)

The calculated F ratios of 5.27 at pretest and 4.43 at posttest shown on table 4.12 indicates a significant difference in aerobic capacity between the forwards and the backs since the two F ratios were greater than the critical value of 3.99 at 0.05 alpha level. The hypothesis that there were no significant differences in aerobic capacity between the forwards and the backs was therefore rejected. This agrees with the results on table 4.11 which indicate that the backs recorded high aerobic capacity (43.9ml/kg/min) than the forwards (40.9ml/kg/min). This reflects the different levels of involvement in their respective positions during training and match play. The findings reflect Reilly’s (1996) observation that each positional role in rugby has unique demands with type and frequency of training varying markedly with the level of play. Kaiser (2005) also concurs that the backs require efficient aerobic fitness since they cover the greatest distance during the game and the necessity to recover quickly from several bouts of intense effort such as sprinting to make scores. A study by Reilly and Kirby (1993) using Rugby Union female players reported similar findings.
where the backs recorded significant increase in VO₂ max than the backs but as the competition progressed the aerobic capacity differences were not significantly different.

Owing to specificity of training as explained by Foss and Keteyian (1998), the VO₂ max of players can vary depending on the positional roles during the game. However, this depends on whether the training programme activities are specific to the game of rugby. The backs and forwards players in Kenya Cup League displayed varying VO₂ max levels since their roles in the game are different and therefore place different physiological demands on the cardio vascular systems of the players.

Garraway (1993) also reports that the position a player holds in the field appears to have a bearing on the probability of being injured. Forwards have the highest probability of injuries where Garraway (1993) has noted that 87% of injuries are due to player-to-player contact during scrimmage and tackling. Depending on severity, an injury may cause a player to miss at least three concurrent matches during the competitive season. This may have led to low aerobic capacity of the forwards participating in Kenya Cup League since their role during the game makes them to be more prone to injuries and therefore are likely to experience a period of inactivity. Garraway (1993) also notes that high proportion of injuries occur at the beginning of the league and mid-way through the competition season. In this study the players were tested at the beginning of the competition and posttest was done mid-way through the competition season. Some of the players may also have been rendered inactive temporarily resulting in low aerobic fitness. Injuries at the start of the league are mainly due to lack of fitness since players may be playing in order to get fit while it should be the other way round.
The backs’ high aerobic capacity may also have been attributed to the fact that during the game these players are involved in a lot of running during the attack phase as opposed to the forwards who mainly are involved in tackling and scrimmage (Kaiser, 2005). The findings also agree with Reilly’s (1990) research findings on USA Rugby Club players’ aerobic capacity during competitive season where the backs recorded high VO$_2$ max of 59.5ml/kg/min and the forward 54.1ml/kg/min. Similar findings have been reported by Hazeldine and Holmyard (1993) in which the back elite female rugby players recorded high aerobic capacity of 47.3ml/kg/min than the forwards’ 43.8ml/kg/min. The two studies attributed the aerobic capacity differences to the greater work-rate demands on the backs. However, a similar study using Japanese inter-college rugby players did not yield significant differences in VO$_2$ max by the forwards and the backs. The findings were an indication that training program for rugby players should be planned in such a way that these activities are specific to the players’ position. Individualized training would allow the players’ physiological system to adapt to the demands of the position occupied during match play.

The low VO$_2$ max levels recorded by the forwards and the backs may be attributed to the fact that Kenyan rugby players started the competitive season at a very low level of aerobic fitness. This is shown by players’ VO$_2$ max values at pre-test shown in tables 4.1, 4.2 and 4.3. Due to great emphasis on skills and tactics, players’ general fitness may have been less addressed. These findings also corroborates with observations by Fender (in Reilly, 1996) that competitive sport generates considerable stress that can lead to burnout resulting in decreased performance capability.

As noted by Gabbett (2000), distribution of labor amongst rugby union players in a team is quite marked, each position having its own training requirements. Therefore, the team-training sessions should focus on practicing team drills and game skills
while physiological fitness should be developed independently by individual players. Reilly (1990), also cautions that physiological fitness is a challenge left to individual players since a person may not pursue training programmes and might rely on match play for training stimuli leading to low aerobic capacity. However, it is vital that the pre-season training lay emphasis on building up the aerobic capacity of players.
CHAPTER FIVE
SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter covers the summary, conclusions and recommendations of the study.

This study investigated the endurance capacity of sixty-nine (69) players from Impala, Harlequins and Nakuru RFC using the multistage shuttle-run test. The study was carried out during the Kenya Cup league 2005. The teams were selected using a stratified random sampling following the 2004 ranking order in Kenya Cup league shown in appendix B.

Player's endurance capacity values were estimated using the Progressive Multistage Shuttle Run Test. A pretest was done at the beginning of the league and a posttest was conducted after eight weeks of training and competition. The following were investigated:

- Aerobic capacity of rugby players between pretest and posttest.
- Aerobic capacity amongst players of different age groups.
- Aerobic capacity of top, middle and the bottom ranked teams.
- Aerobic capacity of the forwards and back position players

5.2 Summary of the Findings

The study yielded the following results:

- There was no significant difference in aerobic capacity amongst the players between pre-test and post-test. The players' VO₂ max at pre-test was 43.14ml/kg/min and at posttest they recorded a mean of 42.62ml/kg/min.
There was no significant difference in aerobic capacity amongst players of different age groups. Players in ages 18-20 recorded mean VO₂ max of 43.42ml/kg/min, those in ages 21-25 and ages 26 and above had a mean of 42.07ml/kg/min and 41.53ml/kg/min respectively. The VO₂ max was higher among the younger players compared to those above 25 years of age.

There were significant differences in aerobic capacities amongst Impala, Nakuru and Harlequins RFC players as indicated by the different mean VO₂ max values. Tukey HSD test revealed the differences were statistically significant. At post-test Impala recorded 44.5 ml/kg/min, while Harlequins and Nakuru recorded 40.2 ml/kg/min and 42.2 ml/kg/min respectively.

There was significant difference in endurance capacity between the forwards and the backs. The forwards recorded 40.9 ml/kg/min and the backs 43.9 ml/kg/min.

5.3 Conclusions

The following conclusions were drawn based on the findings of the study:

a) There was a slight decline in aerobic capacity among the rugby players between pre-test and post-test. The mean VO₂ max recorded at pre-test was 42.5 ml/kg/min and 42.3 ml/kg/min at post-test. This was a slight decline of 0.2 ml/kg/min. The decline was attributed to competition-oriented training adopted by the rugby teams, which has been reported to lead to a drop in players' aerobic capacity.

b) Players' aerobic capacity levels were not statistically significant according to age as was expected. Players in different age groups recorded VO₂ max values that were not significantly different both at pre-test and post-test sessions. This was attributed to lack of consistency in training that is necessary in order
to improve aerobic capacity. However, players below age 25 years had a slightly higher aerobic capacity than those above 25 years though not significant.

c) Aerobic capacity was not a factor that determined performance in rugby as was expected. This is because there was no relationship in finishing order and teams’ aerobic capacity. Impala RFC had the highest VO$_2$ max (44.5 ml/kg/min) and had been ranked in first position in 2004 league (Appendix B) and second position in 2005 league (Appendix G). Harlequin recorded RFC 40.2ml/kg/min and was ranked in fourth and third positions during 2004 and 2005 leagues respectively. Nakuru RFC recorded 44.2 ml/kg/min and was ranked in last position (8$^{th}$ and 7$^{th}$) both in 2004 and 2005 league respectively. The statistically significant differences were attributed to some players recording high VO$_2$ max as they participated in high-level competitions and some teams adopting superior training programmes.

d) The backs had a high VO$_2$ max of 43.9 ml/kg/min than the forwards who recorded 40.9ml/kg min. These differences were attributed to different work rates required of the players in the two playing positions during training and match play. Backs do a lot of running during the game than the forwards.

5.4 Recommendations

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

5.4.1 Recommendations for Policy and Practice

1) The Ministry of Sports, Culture and Social Services in collaboration with Kenya Rugby Football Union should facilitate the transformation of the game to be played on professional basis. This would motivate the players and also
accord them sufficient time for training hence raise performance tactically, technically and fitness-wise.

2) The Kenya Rugby Football Union in conjunction with Schools and Colleges Sports Associations and the Ministry of Education should ensure that the game of rugby is introduced in primary school sporting programme. This will ensure exposure of students to the game at an early age and therefore popularize it in secondary school. This would in turn broaden the player base from which players are selected for national, regional, and international competitions.

3) Rugby coaches should develop and adopt training programmes that are specific to different positions in order to meet the demands of each positional role in a game of rugby. This suggests that the Kenyan rugby coaches need to devise training programmes in a way that players will reap physiological benefits accruing from endurance training.

4) Training programmes should be devised with periodisation taken into consideration in order to allow players reach their peak performance at the right time of the competition. Training should have different activities structured for the off-season, pre-season and in-season.

5) The Kenya Rugby Football Union in partnership with sports scientists, researchers and rugby club managers, coaches, and trainers should organize consultative seminars on regular basis for the purposes of exchanging relevant scientific knowledge, practices and ideas that would improve performance standards in the game of rugby.

6) The Kenya Rugby Football Union should make it mandatory for the rugby teams to keep updated physiological profiles of the players throughout the
league season. Such data would be used as a guide in evaluating suitability of training programmes undertaken by the clubs hence assist in making relevant tactical changes.

5.4.2 Recommendations for Further Research

1) The aerobic capacity levels of rugby players should be investigated during the off-season, pre-season and in-season. This would assist in identifying any changes in fitness profiles of individual players and for the team as a whole. Such data would enable the coaches/trainers to evaluate the training programme activities and make necessary amendments.

2) Further research should be carried out on secondary school teams in order to develop physiological profiles for rugby players of all age categories. This would assist in developing suitable training programmes for players at different levels of competitions.

3) Further research should be conducted to investigate aerobic capacity of rugby players using the most reliable and accurate laboratory techniques such as direct calorimetry. This would yield the most accurate data on players’ VO₂ max.

4) Research should be carried out to investigate the aerobic capacity of all the players who participate in the Kenya Cup league. The data would be used to design suitable training programmes to develop endurance.

5) A study should be carried out to investigate other fitness parameters of rugby players in order to assist the coaches/trainers in developing suitable training programmes to enhance the players’ endurance capacity and performance.

6) Research should be carried out on effects of injuries on endurance capacity of rugby players. Rugby being a high contact game, players are often rendered
inactive and any prolonged period of inactivity can negatively interfere with players’ level of endurance and overall match fitness.
REFERENCES


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</table>
APPENDIX B: RUGBY LEAGUE FINAL STANDINGS SEPTEMBER 2004

STRATA A

1 IMPALA RFC
2 KENYA COMMERCIAL BANK RFC
3 ULINZI RFC

STRATA B

4) KENYA HARLEQUINS RFC
5) NONDESCRIPTS RFC
7) MWAMBA RFC

STRATA C

8) MEAN MACHINE RFC
9) NAKURU RFC
APPENDIX C: THE MULTI-STAGE SHUTTLE RUN FITNESS TEST PROCEDURE

Test Procedure

- Subject places one foot either on or behind the 20meter mark.
- Subject aims to be at the opposite end to the start in time with bleep sound.
- Timing begins slowly but becomes progressively faster each minute.
- The time interval between bleeps decreases such that the subject has to increase the running speed.
- A subject stops when he/she can longer maintain the running speed / keep up with the bleeps.
- A subject’s score is recorded as the final level and number of shuttles completed.
- The subject’s maximum oxygen uptake is estimated using the table provided in appendix A
APPENDIX D: A ONE DAY RUGBY TRAINING ACTIVITIES

During the 2005 Kenya cup league training sessions, a typical training session for players begun with a warm-up that lasted 10 minutes. Warm-up was left to individual players since they did not report for training at the same time. A days’ training comprised of activities such as those shown below. However these activities varied each day with each session lasting 1 ½ to 2 hours, two days a week from 5.30 pm to 7 pm.

<table>
<thead>
<tr>
<th>Activities</th>
<th>time</th>
</tr>
</thead>
<tbody>
<tr>
<td>power-sprinting</td>
<td>10 min.</td>
</tr>
<tr>
<td>zigzag passing</td>
<td>10 min.</td>
</tr>
<tr>
<td>three players, 2 balls</td>
<td>10 min.</td>
</tr>
<tr>
<td>forwards around the cones</td>
<td>10 min.</td>
</tr>
<tr>
<td>back line continuity</td>
<td>10 min.</td>
</tr>
<tr>
<td>centre attack drill</td>
<td>10 min.</td>
</tr>
<tr>
<td>team station drills</td>
<td>10 min.</td>
</tr>
<tr>
<td>15 aside game</td>
<td>15 min.</td>
</tr>
<tr>
<td>cool-down</td>
<td>10 min.</td>
</tr>
</tbody>
</table>

Total time: 135 minutes
APPENDIX E: AEROBIC CAPACITY LEVEL EVALUATION
PROTOCOL SHEET

NAME: ..............................................................

AGE: ..............................................................

TEAM: .............................................................

POSITIONAL ROLE: ..............................................

<table>
<thead>
<tr>
<th>1ST TEST</th>
<th>LEVEL</th>
<th>SHUTTLE</th>
<th>PREDICTED V0₂ MAX</th>
</tr>
</thead>
<tbody>
<tr>
<td>POST-TEST AFTER 8 WEEKS</td>
<td>LEVEL</td>
<td>SHUTTLE</td>
<td>PREDICTED V0₂ MAX</td>
</tr>
</tbody>
</table>
APPENDIX F: A SAMPLE OF THE LETTER USED FOR THE REQUEST OF PLAYERS PARTICIPATION

Janet Wanjira Kamenju  
Kenyatta University  
Department of Exercise, Recreation and Sport science  
P.O Box 43844  
Nairobi.  

To the Team Coach/Trainer,
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Dear Sir,

RE: REQUEST FOR ASSISSTANCE IN RESEARCH

I am a postgraduate student taking a Master of Science course in the Department of Exercise, Recreation and Sport Science.

I intend to carry out an assessment of aerobic capacity of rugby players taking part in the Rugby Union League 2005 edition. Your team has been identified for the study. I plan to carry out the first test at the beginning of the league and then a re-test after eight weeks. The focus of the test will be the assessment of aerobic capacity as an indicator of individual players' cardio respiratory endurance.

It is hoped that the test will not endanger the players in any way. The results of the study shall be made available to your team for the purpose of improving training. I will greatly appreciate your assistance and cooperation for the success of the study. I thank you in advance.

Yours sincerely,

JANET WANJIRA KAMENJU
APPENDIX G: KENYA RUGBY LEAGUE FINAL STANDINGS AS PER SEPTEMBER 2005

1. KENYA COMMERCIAL RFC
2. IMPALA RFC
3. HARLEQUINS RFC
4. MWAMBA RFC
5. NORNDESCRIPTS RFC
6. MEAN MACHINE RFC
7. NAKURU RFC