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Performance Diagnostics Quantitative Methods To Provide Training Consequences

Empirical Study To Development And Evaluation Field Team Sports

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Wuppertal, 2013

Declaration

I hereby declare that “Performance Diagnostics Quantitative Methods To Provide Training Consequences” is my own work and it has not been submitted before for any other degree in any other university. To the best of my knowledge and belief, the thesis contains no material previously published or written by other person except where due reference is made.

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Abstract

Football codes sports have been many studies, which investigated the physical fitness profiles of these sports, but especially in the case of soccer. However, some physical fitness components of these sports are poorly understood. Furthermore, there are individuals who have competed at elite level in soccer and rugby union. There are a few studies have been compared the physical fitness characteristics of elite level players in each of the football codes. Therefore, the current study describe a physical fitness profile for soccer and rugby players, and determine if there are any differences in theses fitness characteristics between both field team sports.

Twenty-eight players participated in this study. Both field team sports play at high-level competitions. Fourteen of them are soccer players from a Bundesliga Club (age 24.57 ± 4.33 years; height 1.85 ± 0.07 m; weight 83.86 ± 8.5 kg; BMI 24.50 ± 1.45 kg·m⁻²), and the other fourteen are international rugby players from DRV federation (age 24 ± 3.94 years; height 1.81 ± 0.05 m; weight 91.05 ± 12.16 kg; BMI 27.77 ± 2.33 kg·m⁻²). All players completed performance diagnostic tests in speed, strength and endurance aerobic capacity in the season break phase.

The results showed significant difference in BMI and physical fitness characteristics (speed, strength and endurance) between soccer and rugby players, although no significant difference observed in anthropometric (age, height, and weight), speed (non-linear sprint 8 m, 22 m and 2.Ch), strength (1RMbp and 1RMbs) and endurance aerobic capacity (VO_{2max} test). In conclusion, the results together with collected results from the literatures revealed significant differences between soccer and rugby union sports, and indicate that the demands of both field team sports are different. This difference should be considered by those designing the conditioning fundamentals of training programmes for these sports.

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Glossary of terms

The following abbreviations have been used frequently throughout the text of this thesis:

1

1RMbp = One repetition maximum bench press

1RMbs = One repetition maximum back squat

1.Ch = First change turn

2

2.Ch = Second change turn

B

BMI = Body mass index

C

cm = Centimeter

D

DFB = German soccer federation

F

Fig. = Figure

FLT = Research center for performance diagnostics and training advice at University of Wuppertal

FLT Z-Run Sprint = Non-linear zigzag run sprint acyclic test designed by research center for performance diagnostics and training advice at University of Wuppertal

K

kg = Kilogram

$\text{kg}\cdot\text{m}^{-2}$ = Kilograms per square meter

M

m = Meter

min = Minutes

$\text{ml}\cdot\text{min}^{-1}\cdot\text{kg}^{-1}$ = Millilitres of oxygen per kilogram of body weight per minute

P

p. = Page

ρ = Significant level

R

r = Correlation coefficient

S

SD = Standard deviation

sec = Seconds

T

Tab. = Table

V

$\text{VO}_{2\text{max}}$ = Maximal oxygen uptake

1. Introduction

Football refers to a number of sports that involve kicking a ball with the foot to score a goal. The most popular of these sports worldwide is association football that known as soccer. The word football applies to whichever form of football is the most popular in the regional context in which the word appears that including association football, as well as American football, Australian rules football, Gaelic football, rugby league and rugby union. These variations of football are known as football "codes" (Reilly & Gilbourne, 2003).

Soccer is the most popular sport in the world with approximately 200.000 professional and 240 million amateur players. A soccer match is played with two teams of 11 players and divided into four groups (goalkeepers, defenders, midfielders and forwards). A match comprises two halves of 45 min with an interval of 15 min (www.fifa.com).

Rugby union is a full body contact game, a popular sport and is second only to soccer in terms of the number of nations in which it is played. Two teams of 15 players play a rugby union match a side (eight forwards and seven backs). A match comprises two halves of 40 min with a 5-10 min half time break (www.irb.com).

Sports performance is an integrated approach to training players to reach peak levels of performance during the competition season. There are many important physical characteristics required to improve this performance for players in field team sports such as soccer and ruby union sports. Although each of these sports has different skills, tactics and movement patterns during match play but they have similar fitness demands such as speed, agility, strength and endurance, these components of physical fitness¹ related to successes in matches in these field team sports.

In highlighted review in sports science research, soccer was compared to football codes such as Gaelic Football, American football and hurlers (McIntyre,

¹ Physical fitness defined in this study as a combination of anthropometric and physical performance characteristics. In addition, the physical performance characteristics defined in this study as the outcome of the following fitness components: speed, strength and endurance.

2005; Strudwick et al., 2002). A direct comparison between soccer and rugby sport has not been conducted in physical fitness except four studies, study by (Walsh et al., 2005) was purposed to develop sprint test batteries, study by (Junge et al., 2004) was to compare the characteristics and incidence of injuries in amateur soccer and rugby players, study by (Brick & O'Donoghue, 2005) was examined the fitness characteristics of players at an elite level between soccer, rugby and Gaelic football. In addition, (Kuhn, 2005) has determined whether any differences in physical fitness between soccer and rugby players.

The results of (Brick & O'Donoghue, 2005) demonstrated that rugby forward and back players relatively had higher means \pm SD than soccer players in body weight 100.2 ± 9.2 , 84.5 ± 4.7 and 81.4 ± 8 kg, respectively; one repetition maximum bench press (1RMbp) for upper body 109.7 ± 26.7 , 88.6 ± 7 and 80 ± 11.7 kg, respectively; and maximal oxygen uptake VO_{2max} of 20 m shuttle run test 54.1 ± 2.6 , 59.6 ± 4.7 and 51.3 ± 4.4 $ml \cdot min^{-1} \cdot kg^{-1}$, respectively. However no significant difference observed between rugby forward players and soccer players in estimated VO_{2max} , while rugby back players showed higher significantly difference than soccer players. The authors in this study recommended that designing the conditioning elements of training programmes for soccer and rugby players should consider this difference.

In the same line, study of (Kuhn, 2005) reported that soccer players had lower means \pm SD than rugby players in height 1.76 ± 8.8 and 1.84 ± 6.5 m and body weight 72.8 ± 7.9 and 88.2 ± 13.7 kg, respectively. However, in this study soccer players had better sprint time means \pm SD in agility test than rugby players 7.5 ± 0.7 and 8.0 ± 0.6 sec. Rugby players had significantly higher absolute upper leg strength scores than soccer players, although both soccer and rugby players did not differ in their relative strength scores.

In context of development fitness test batteries, the study of (Walsh, et al., 2005) analyzed the correlation between three performance sprint tests for soccer and rugby players, which included a linear sprint 40 m, a course shaped like an 'L' run, which the players had to complete both 90 and 180 degree turns during the

sprint and a zigzag sprint test as non-linear sprint tests. The results of this study reported that the ability to run fast in a straight line does not seem to be the same as the ability to perform cutting moves or change directions in soccer and rugby game.

(Junge, et al., 2004) described the injuries in soccer and rugby union sports and reported that comparisons between soccer and rugby injuries clearly indicates that rugby sport is associated with a higher rate of injury than soccer. Specifically, the incidence of match injuries was more than twice as high in rugby players compared with soccer players.

The differences between reviewed results of the above few studies, which compared soccer and rugby players, could be explained by the demands different of both sports. Rugby union can be characterized as typical stop and go games, whereas soccer is a relatively continuous game that requires a higher degree of aerobic power. (Reilly & Borrie, 1992) suggested that sports such as soccer and rugby union could be described as intermittent sports, because their demands of bouts is high-intensity play combined with periods of sub-maximal effort over a long period that uses both aerobic and anaerobic energy systems.

Soccer as a most competitive field team sports, is an intermittent based game. Performance in intermittent based sports has been linked to speed, power, strength, agility and the ability to repeat short high intensity bursts throughout a match, rather than the capacity to maintain a steady sub-maximal work rate (Bangsbo et al., 1991; Stolen et al., 2005).

Rugby union is a field team sport that has a variety of physiological responses as a result of repeated high-intensity sprints and a high frequency of contact. The physiological demands of rugby union require a high level of strength and powers, for example scrum² and sprinting, are combined with periods of lower

² The scrum skill in rugby is a way to restart play after a minor infringement or a stoppage. A scrum is formed in the field of play when eight players from each team, bound together in three rows for each team, close up with their opponents so that the heads of the front rows are interlocked. This creates a tunnel into which a scrum half throws in the ball so that front row players can compete for possession by hooking the ball with either of their feet (www.irb.com).

intensity aerobic activity and rest (Duthie et al., 2003; Nicholas & Baker, 1995; Quarrie et al., 1995).

Physical characteristics demands and game strategy in soccer and rugby union are relatively similar for both sports. Tactical strategy generally involves isolating the defensive players and picking a place on the field to move the ball forwards towards a goal. The difference between soccer and rugby union is that rugby players need more power to drive the ball across the field through the opposing team. However, the basic skills for soccer and rugby players are also relatively similar when every player needs to be able to kick, tackle, pass and run fast. Nevertheless, there are some of different specializations in soccer game, where specific skills are necessary for given situations in the game.

Whether strategy game play in soccer and rugby union sports similar or not, (Walsh, et al., 2005) found one reason for the occurrence of acyclic sprints in rugby union and soccer. This reason is that in both sports there are opponents from the other team, which have to be avoided on the way towards the goal. Soccer and rugby players to successes in this tactical strategy game, players needs the ability to either run extremely fast in relatively straight line to run past the opposing player or to be able to change direction quickly and outmaneuver the opposing players.

The popularity of and participation in field team sports such as soccer and rugby union are extensive throughout many countries worldwide. In addition to the general interest in these field team sports, the sport scientists have investigated many aspects of actual and simulated performance in order to gain a greater understanding of the physiology of these complex games (Bangsbo, 1994a; Bangsbo, et al., 1991; Duthie, et al., 2003; Hoff & Helgerud, 2004; Nicholas & Baker, 1995; Reilly, 1997; Stolen, et al., 2005).

Soccer and rugby union as a football codes sports have been many studies that investigated the physical fitness characteristics of these sports, but especially in the case of soccer. However, some physical fitness components of these sports are poorly understood. Furthermore, there are individuals who have competed at

elite level in soccer and rugby union. It has previously been noted that there are a few studies have been compared the physical fitness characteristics of elite level players in each of the football codes (Strudwick, et al., 2002).

In recent years more sport scientific studies have focused on soccer sport in the anthropometric characteristics, aerobic fitness assessment, explosive power, and physiological responses of players during training and games. The survey search from recent to June 2012 of previous studies by Pubmed database showed, that rugby union sport has a few specific scientific studies Tab. 1. There are many of the current training methods demand on scientific research knowledge from other football codes and could be adapted for rugby union if this possible, as that reported between soccer and Gaelic football (Reilly & Doran, 1999).

Moreover, there are few studies that compared directly the physical fitness characteristics in soccer to rugby union and some of other football codes, except few studies, which reported by (Brick & O'Donoghue, 2005; Jardine et al., 1988; Kuhn, 2005; Strudwick, et al., 2002).

Tab. 1: Search results for scientific papers using PubMed database

Sport (Keyword search)	Number of published studies
Soccer	4707
Rugby League	631
Rugby Union	391
Gaelic Football	30

A review of literature showed, that the physical fitness characteristics tests for field team sports such as soccer and rugby union are important to utilize tests, which demonstrate construct validity when conducting sport specific evaluation for field team sports players. Thus given the lack of research and the increasing number of participants in field team sports, there is a need to identify and develop a mechanism to profile, monitor, and evaluate these players.

The lack researches of physical fitness tests in rugby union Tab. 1 and also the development of the players profile are a motive to conduct current study. This is of great importance for coaches and players in order to identify the best

methods, which using to find the appropriate solutions to provide training and to control and guide the training process according to the general requirements in soccer and rugby union games.

Therefore, the primary aims of this empirical study were to describe and assess the physical fitness characteristics profile for German soccer and rugby players in order to:

1. Describe a physical fitness profile for soccer and rugby players.
2. Establish a normative data for German elites and non-elites male soccer and rugby players.
3. Determine if there are any differences in physical fitness characteristics between soccer and rugby players as recommendations of pervious studies.

2. Theory Review

This part of current study will focus on different aspects of soccer and rugby union in terms of the physical fitness characteristics and the general requirements game in both sports. The theory part begins with a background about the importance and benefits of used physical fitness tests in field team sports such as soccer and rugby union. Other topics that will be discussed include the demands of the game and physical fitness characteristics for soccer and rugby players will be compared with the international previous studies.

2.1 Physical fitness testing

Physical fitness testing for field team sports players is a very important and imperative part of research and development within a particular sport. It allows investigators to establish norms and thus make objective comparisons between players in different ages, genders, and level of leagues from other countries. Such information about fitness demands can be obtained by using fitness tests that evaluate physical performance capacity.

2.1.1 Definition of fitness testing

A physical fitness test is a test designed to measure physical speed, strength, agility and endurance. (Reiman & Manske, 2009) have defined a testing as using a set of problems to assess abilities. Therefore, performance testing means using a set or tool of tests to determine performance abilities or functional limitations. A functional limitation is the inability to perform a particular activity at a normal level.

In addition, (Coulson & Archer, 2009) have defined testing as a statement about the quality or value of what has been measured and thus involves the tester making a decision, so interpreting a score for each player. This mean, it is first necessary to define the intent of baseline testing and then develop a practical model for application.

The fitness testing means in German literatures “Leistungsdiagnostik”, this word means performance diagnostic. There are several German authors have been defined the physical fitness testing as a process that use some tools to control

and advise coaches or players to reach a peak performance during the game. (Thiess & Schnabel, 1995) have defined fitness testing as „The performance diagnostics includes the methodology of training, methods of control, performance assessment, sport motor tests, observation and analysis procedures and the test methods of biomechanics, biochemistry, physiology, sports medicine and sports psychology“. (Martin, 1980) has distinguished five types of performance diagnostics tests, which includes the motor skills tests, biomechanics performance diagnostic, standardized competition or game observation, sports medicine and biochemical function tests and psychological tests.

(Reinhold, 2008) also defined the performance diagnostic as a term and identify of the individual components, a level of player performance or a performance condition and it is used to training management and control. According to (Schiffer, 1993) who showed that performance diagnostic, performance control and training plan have a very close relationship to each other. Therefore, these components could not be isolated in the complex training control. The below Fig. 1 present the internal relations between various components to each other.

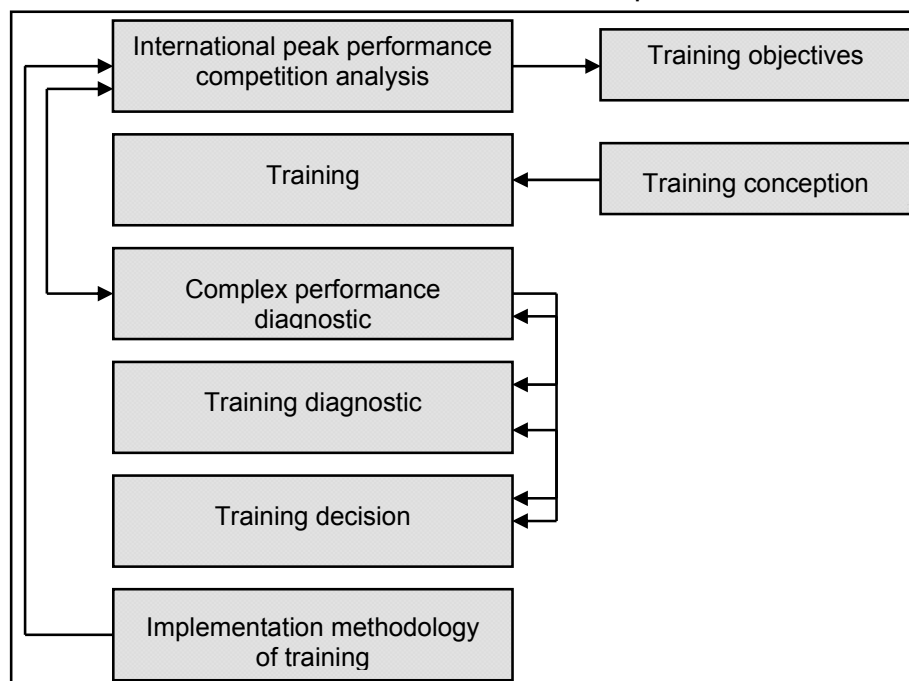


Fig. 1: The functional chain for developing the sport specific performance (Martin, 1999), page 37.

A review of different fitness tests definitions shows that the determination of performance status for sport players related with more factors as demands of every sport, age and gender. Furthermore, the influence of these factors size on player performance will be influencing the results of the complex performance tests.

2.1.2 Benefits of fitness testing

It is important to optimize and develop player performance and this process to assess a player performance requires a determination of requirements and the continuous determination of physical performance using appropriate methods and procedures. The aim is to assess the performance achieved as quickly as the players.

Performance tests for sport players can be designed to cover the physical fitness components, technical and tactical of the game. Fitness testing is used throughout players to document, assess and predict sports performance (Bangsbo, 2003).

It is important that the players and coaches obtain objective information about the player's physical fitness characteristics to clarify the objectives of training. A successful training program for these players is one that will maximize all of the required skill and fitness components of the game. An essential part to any training program is fitness performance testing, which can help identify weaknesses, monitor progress, provide feedback, educate coaches and players, and predict performance potential (Bangsbo, 2003; Carling et al., 2009).

Fitness tests are the only effective and objective way to evaluate a training program. The use of post testing data permits accurate evaluation of many qualities. A coach will be able to see progress since the player's previous tests or compare data with a previous group of players of the same age, position, or experience (Bisanz & Gerisch, 2008a; Schmid & Alejo, 2002). The particular test mode and outcome measures chosen must therefore be selected carefully in order to meet the objective of monitoring the effectiveness of player's physical preparation (Cronin & Hansen, 2005).

Physical fitness characteristics of player in top sports depends on the players technical, tactical and physiological characteristics. These components are closely linked to each other. In sports such as soccer and rugby union, players perform different types of exercise ranging from standing still to maximal running with varying intensity. Therefore, Competitive naturally provides the best test for players, but it is difficult to isolate the various components within the sport and get objective measures of sport performance without performance testing for all players. Fitness testing can provide relevant information about specific parts of a sport (Bangsbo, Mohr, Poulsen, et al., 2006).

Thus performance diagnostic is important tool for both players and coaches, who would uses it as a predict factor for their training process and consequences, weather in top level elite sports or to improve non-elite players and for identification talent in field team sports as soccer and rugby union.

(Freiwald et al., 2008) have identified, how coaches and players in high elite soccer levels take advantages from performance diagnostics data, as an important feedback and consequences for their training monitors and process Fig. 2, and also reported that training aims will be achieved from documented (databank) performance diagnostics tests through each of special training sessions, physiotherapy, adjuvant medical, psychological and nutritional measures.

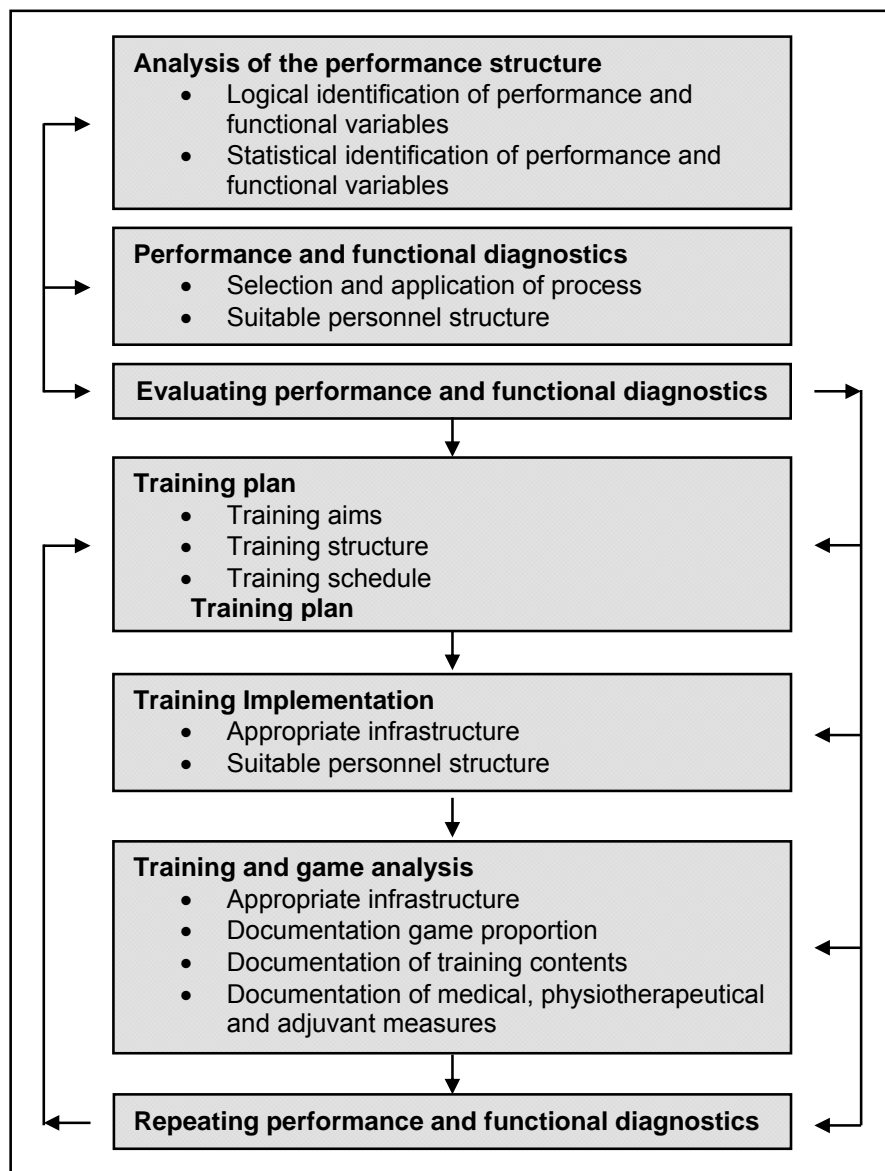


Fig. 2: Block diagram of performance and function diagnostics in high elite soccer players (Freiwald, et al., 2008), page, 22.

The recommendation of (Freiwald, et al., 2008) about the advantages of performance diagnostics data as a feedback and consequences for training process consistent with (Baechle & Earle, 2008) who suggested that the end of the competitive season, coaches should assist each players in establishing training goals for the off-season and help develop the using programs needed to achieve those goals.

There are many reasons for performance testing and evaluating training processes. (Bangsbo, 2003; Carling, et al., 2009; Dick, 2007; Ebben, 1998; Gamble, 2010; Reiman & Manske, 2009; Reinhold, 2008; Sayers et al., 2008; Thiess & Schnabel, 1995) demonstrated the next reasons for performance tests, which all field team sports as soccer and rugby players and coaches need it to be successes in their sport:

- to assess the current physical state of the players,
- to study the effect of a training programme,
- to motivate players to train harder,
- to give players objective feedback,
- to make players more aware of the objectives of the training,
- to evaluate whether a players are ready to play a competitive matches,
- to plan short and long term training programmes,
- to determining players positions placement and ranking them,
- to establish homogeneous groupings for training and place players in small sides training,
- to establish the physical characteristics demanded of a given sport,
- to identify a relationship between individual performance capacities and demands of competition,
- to monitor progress during rehabilitation or determine whether an athlete is ready to compete and monitor his health status,
- to examine the development of performance from year to year,
- to enable future performance to be predicted, and
- to provide data for scientific research on the limitations of performance.

Fitness tests results provide baseline scores on various measures of player's ability, so that realistic goals can be set and degree of improvement quantified.

The following points should be considered when establishing aims for the player:

- the coach must be aware of the basic physical abilities required for performance at the competitive level of the team and how can make training for this,

- the coach must have enough knowledge about exercise science to have a good idea of what a training program can achieve for each individual on the team and also designed for every time in season,
- the coach should encourage players to internalize the goals to promote the physical, mental, and emotional commitment necessary to work toward the goals,
- players should keep one or more copies of the goals in places where they will be seen daily, and
- players should make their goals known to their training partners so they can work together and motivate each other to achieve their goals (Baechle & Earle, 2008).

Physical fitness tests will be useful if it is repeated at regular intervals and same procedures. In this way can progress be monitored or issues affecting performance be identified. Therefore, the accurately physical fitness tests must be selected tests that are valid, reliable and objective. From this background, it is necessary to present and understand the scientific criteria of measurement methods.

2.1.3 Criteria of fitness testing

There is a need for a review of quality criteria and the feasibility of physical fitness characteristics tests in field team sports. (Baechle & Earle, 2008; Dick, 2007) demonstrated that the fitness testing procedure must be objective (consistency of result and irrespective of tester), reliable (consistency of reproduction) and valid (testing what it purports to test). These three characteristics are the key factors in evaluating test quality and must be present for the test to be beneficial.

2.1.3.1 Test objectivity

Objectivity is known as intertester reliability. A test that is objective will produce the same results for the same players, regardless of the tester, or technician administering the test. Objectivity is quantified by calculating the correlation between pairs of test scores measured on the same individuals by two different

technicians. The value of correlation is known as the objectivity coefficient. The most of physical fitness tests have high objectivity coefficients ($r > 0.90$), especially when technicians are highly trained, practice together and carefully follow standardized testing procedures (Heyward, 2006). The correlation coefficient used as a measure of objectivity, which is calculated from the collected test findings of various investigators on a sample of subjects.

The following Tab. 2 according to (Bös et al., 2000) present the evidence interpretation of correlation coefficients:

Tab. 2: Evidence interpretation of the amount of correlation coefficients (Bös, et al., 2000), page, 169.

r – value			Significant
	=	0.00	No correlation
0.00	≤	0.39	Low correlation
0.40	≤	0.69	Moderate correlation
0.70	≤	0.99	High correlation
	=	1.00	Perfect correlation

The choice and quality of fitness tests equipments are essential factors in measuring and assessing key components of physical fitness performance. (Carling, et al., 2009) according to (Katz, 2001) showed, that the criteria for success of the various applications and resources used to assess contemporary performance in sport should:

- be based on techniques that are currently being used and for which there is clear evidence of success,
- address clearly defined and measurable needs,
- be interactive and responsive, in real time, to client needs,
- be transferable yet customizable across sporting environments,
- result in positive changes which may impact on attitudes, performance and/or costs, and,
- integrate technology with easy to use interfaces that are reliable, effective, efficient and transparent to the user.

2.1.3.2 Test validity

Fitness tests must measure the component of fitness that they are supposed to. Validity refers to the degree to which a test or test item measures what it is supposed to measure and it is the most important characteristic of testing. Thus, validity refers to the ability of the interpretation of scores from a fitness test and the most important consideration in measurement (Baechle & Earle, 2008; Thomas et al., 2011).

With regard to physical fitness testing, test validity is the ability of a test to measure accurately, with minimal error and a specific physical fitness component. Reference and criterion methods are used to obtain direct measures of fitness components. However, some fitness components cannot always be measured directly and requiring the use of indirect measures for estimation of the value of the reference measure (Heyward, 2006).

According to (Baechle & Earle, 2008; Thomas, et al., 2011) who considered that the validity involves four types that known as face, content, criterion and construct validity:

1. **Face Validity** is the degree to which a measure obviously involves the performance being measured and also known as logical validity. If a fitness test item has face validity, the player is more likely to respond to it positively.
2. **Content validity** is the assessment by experts that the fitness test covers all relevant subtopics or components abilities in appropriate proportions. Examples of component abilities in players are jumping ability, sprinting ability and muscular strength of the arms.
3. **Criterion validity** is the degree to which scores on a fitness test are related to some recognized standard or criterion. There are three types of criterion validity: concurrent, predictive and discriminate validity. The **concurrent validity** is the extent to which test scores are associated with those of other accepted tests that measure the same ability. **Predictive validity** is the extent to which the test score corresponds with future behavior or performance; this will be measured through comparison of a

test score with some measure of success in the sport itself. **Discriminate validity** is the ability of a test to distinguish between two different constructs and is evidenced by a low correlation between the results of the test and those of tests of a different construct.

4. **Construct validity** is the ability of a test to represent the underlying construct and refers to overall validity, or the extent to which the test actually measures what it was designed to measure.

In addition to test validity, test sensitivity and specificity are often reported. Sensitivity refers to the probability of correctly identifying individuals who have risk factors. Specificity is a measure of the ability to correctly identify individuals with no risk factors (Heyward, 2006).

2.1.3.3 Test reliability

Reliability is a measure of the degree of consistency or repeatability of a test. If a player his ability does not change, when measured two times with a perfectly reliable test, the same score is obtained both times. In an unreliable test, the player could obtain a high score on one day and a low score on another, thus a reliable test produces must be gave the same results if repeated (Baechle & Earle, 2008).

It is important to know that the fitness test reliability affects test validity. Tests with poor reliability will be also having poor validity because unreliable tests fail to produce consistent test scores. Also it is possible for a fitness test to have excellent reliability but poor validity. Even, when a test yields stable and precise values across trials or between days (Heyward, 2006).

There are several ways to determine the reliability of a fitness test. The most obvious one is to administer the same test twice to the same group of players. Statistical correlation of the scores from the two administrations provides a measure of test-retest reliability. Any difference between the two sets of scores represents measurement error, which can arise from any of the following factors:

- intrasubject (within subjects) variability,
- lack of interrater (between raters) reliability or agreement,

- intrarater (within raters) variability, and
- failure of the test itself to provide consistent results.

Intrasubject variability is a lack of consistent performance by the person tested. Interrater reliability, also referred to as objectivity or interrater agreement is the degree to which different raters agree (Baechle & Earle, 2008).

(Reiman & Manske, 2009) has been defined the two main forms of reliability:

1. **Intrarater reliability** is the reliability of a test of measurement based on the degree of similarity of results obtained by one rater during different performances of the given test.
2. **Interrater reliability** is the reliability of a test of measurement based on the degree of similarity of results obtained from different researches using the same equipment and methods.

Finally, fitness tests to be valid it must be reliable, but a reliable tests may not be valid because the test may not measure what it is supposed to measure. For more details and descriptions of reliability specifications methods, it will be found in (Baechle & Earle, 2008; Reiman & Manske, 2009; Thomas, et al., 2011).

2.2 Physical characteristics of soccer and rugby players

The aim of sport training for every high level sport requires an understanding of the physical and physiological characteristics that demands of the game, which motivated the players in competition. The scientific studies that investigated the differences between field team sports such as all football codes sports very important to describe the trends of modern training methods.

The physical fitness demands in field team sports and training are closely dependent on the physical capacity of the player, technical abilities, and tactical role, playing position, style of playing, the opponent, as well as numerous environmental and internal factors. These elements are closely linked to each other, for example the technical quality of players may not be utilized if the player's tactical knowledge is low. The physical fitness characteristics demands in sports games are related to the activities of the players during their matches (Mohr et al., 2003). In some sports as soccer and rugby union, it is very important for the players to have a very high physical capacity at least in one of the categories to perform at a top level and players may need an all-round fitness level (Bangsbo, et al., 2006).

Physical fitness and physiological profile investigations in field team sports have been conducted in soccer (Hoff & Helgerud, 2004; Pieper et al., 2010; Reilly & Williams, 2003; Reinhold, 2008; Sporis et al., 2009; Stolen, et al., 2005; Svensson & Drust, 2005; Tumilty, 1993) and in rugby union (Deutsch et al., 2007; Duthie, et al., 2003; Maud, 1983; Nicholas & Baker, 1995; Reilly, 1997; Rigg & Reilly, 1988; Roberts et al., 2008). In addition, a direct comparisons in some physical characteristics between soccer and rugby players have been also investigated by (Brick & O'Donoghue, 2005; Kuhn, 2005).

In general, soccer and rugby players require; moderate aerobic capacity between $55-65 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ depending on their positions, a high anaerobic power, quick recovery between high intensity work bouts, high acceleration rate from different position at speed, the ability to change their directions and a superior vertical jump performance.

In addition, rugby union as contact football codes require players to have a high degree of muscularity, combined with exceptional levels of upper and lower body strength and power. Thus, an understanding of the components of the physical fitness characteristics in soccer and rugby players is very important to describe and profile these players at high top levels.

2.2.1 Anthropometric and personal characteristics

Anthropometric and personal characteristics involve more factors such as age, height, weight and body mass index (BMI). In this section, only age, height and body weight and (BMI) of soccer and rugby players would be focused on.

2.2.1.1 Definition of anthropometric

(Reiman & Manske, 2009) define anthropometry as, the science of measuring the physical parameters of the human body. Anthropometry is often used to evaluate a player's size, shape, body proportions, body composition and degree of asymmetry between the dominant and non-dominant limbs.

(Heyward, 2006) has defined also the anthropometry, as the measurement of body size and proportions. The measurement includes body weight, height, circumference, skinfold thickness, bone widths and lengths.

Anthropometry includes the measurements of age, weight, height, specific segment lengths, skeletal breadths, limb circumferences and skinfold thickness. And it is a series of systematized measuring techniques that express quantitatively the dimensions of the human body (Maud & Foster, 2006).

Different field team sports have different anthropometric characteristics, therefore specific anthropometric variables should be used for talent identification in different sports and describe the elite top levels players such as soccer and rugby players.

2.2.1.2 Anthropometric and personal characteristics of soccer players

For many sports, there are specific physical characteristics, which indicate suitability for, or potential to compete in this sport at the highest level. Anthropometric characteristics of players have been shown to be responsible

predictors for participation at the highest level in sports such as soccer. (Hazir, 2010) reported that, In order to compete at an elite level, soccer players are expected to possess morphological and physiological characteristics, that are applicable both for the sport of soccer and specifically to their playing position.

The assessment and determination of the anthropometric characteristics is essential to a successful achievement of a soccer team not only during a game but also during the whole season. This information about anthropometric characteristics can and must be used by the coach to change the player's function or even the tactical formation of the whole team, with the purpose to maximize the performance, once each positioning presents specific features (Shephard, 1999). In addition, there are anthropometric and fitness predispositions for the different playing positions within soccer.

Significant differences in a variety of anthropometric characteristics such as height and body weight have previously been reported across soccer players, suggesting that these variables denote a morphological optimization within soccer and that anthropometric measurement of players should therefore be an integral part of a performance profiling program (Da Silva et al., 2008; Reilly et al., 2000).

2.2.1.2.1 Age of soccer players

(Reilly, 1996) stated that world top class soccer players tended to have an average age of 26-27 years with a standard deviation of about 2 years. Goalkeepers seem to have a longer career life than players in other positions. (Bangsbo, 1994c) discovered that the average age of goalkeepers were higher than other positions in the teams. As (Reilly, 1996) explained the age difference might be because the goalkeepers had a relatively lower possibility of chronic injuries and degenerative trauma.

Players in elite levels are generally at their peak playing power in the age of 25 years. In this age they have been exposed to high level training or practice for \pm 10 years in accordance with the 10 year rule to achieve an exceptional standard of performance. Their peak playing ability generally lasts for 5-6 years, because

at this age the player has acquired the peak levels of fitness that the game requires combined with the time spent training and honing their specific skills (Helsen et al., 2000).

The optimal peak playing age for an elite soccer or individuals players, at which they perform their best is said to be in the range of 24-27 years. In this study, the mean age of the soccer players is 24.57 ± 4.33 years, current study relatively confirmed the results of (Bloomfield et al., 2005) who reported mean age for Bundesliga players of 23.2 ± 1.1 years and 23 ± 1.2 years from 4 European soccer leagues.

In any case, (Shephard, 1999) shows that the mean difference age years between soccer players at elite levels is unclear however, the increase in average age range of the soccer team versus the peak playing age range, is determined by an accumulation of skills, incipient deterioration in physical characteristics or loss of personal motivation. However, with the advancement in training methods and the continued exposure of elite skills and playing tactics to players at a younger age, it would not be unexpected of elite soccer players to reach their peak playing potential one or two years earlier, which could enable them to perform optimally for longer.

2.2.1.2.2 Height of soccer players

Height might be a factor to determine which position a player played. Obviously, the tall players tended to have advantages in certain positions such as goalkeepers. (Reilly, et al., 2000) stated that there were likely to be anthropometric predisposition for positional roles, the taller players were seems the most suitable for central defensive positions and for the target player among the strikers or forwards. (Matkovic et al., 2003) suggested that body height is favorable for defenders in actions in which the ball is received or fought for by the head and on the jump or standing on the ground. Body height is, therefore, definitely important when directing a player towards specific position related or tactical roles in the game.

(Al-Hazzaa et al., 2001; Bangsbo, 1994c) reported that in order to a team to be successful, it is essential that both its center backs and the goalkeepers have a privileged height, as they perform a higher amount of vertical jumping, and thus, they are willing to be successful in their movements. Opposite to this, running backs, midfielders and strikers are lower and rather run with the ball, and they are quicker, and this fact grants to them an additional advantage against the center backs.

In a study by (Bangsbo, 1994b) of 65 elite Danish players, goalkeepers and central defenders were the tallest 1.90 ± 0.06 and 1.89 ± 0.04 m, respectively. However, the mean height of full-backs, midfield and forwards players were relatively similar 1.79 ± 0.06 , 1.77 ± 0.06 and 1.78 ± 0.07 m, respectively. Within each group of Danish soccer players, a large range was observed (e.g. the tallest forward was 1.90 m and the shortest was 1.67 m). This variability of height mass may be influence the tactical role allocated to the individual players. The tall forward might be used as a target player for high balls, whereas the short forward may prefer to run for balls played deep into the opponent's defense.

(Matkovic, et al., 2003) stated that, it is highly probable that the height itself does not guarantee the success in the game. Nevertheless, it is also likely that a particular body height at a younger age has an important role in the selection of players as for determining their position in play even before entering the senior competition level and accordingly the adaptation of training. Additionally, when dealing with body height, the fact that it is connected with the ethnic component should be taken into consideration. For instance, the Asian players are on the average significantly shorter than European or American players.

2.2.1.2.3 Body weight of soccer players

(Reilly, 1996) has been noted that a particular body size usually results in a player acquiring certain skills and gravitation towards a specific playing position or role within the team. (Reilly, 1990) pointed out that body mass played an important role in fitness for soccer player. Also, excess mass in form of fat might

be detrimental to player's performance. Furthermore, reported that low percentage body fat would generate higher forces for jumping, kicking and tackling. (Bangsbo, 1994b) observed that, goalkeepers and central defenders elite soccer players were the heaviest, while the mean body mass of full-backs, midfield players and forwards were relatively similar in body weight.

Regional differences in the physical make-up of soccer teams across Four European professional soccer leagues are shown to exist with players from the German Bundesliga, reporting higher values for body mass and BMI than players from the English Premier League, Spanish La Liga Division and Italian Serie A (Bloomfield, et al., 2005), and reported, it could be suggested that play in the Bundesliga is based on power and athleticism. (Reilly & Williams, 2003) found that the soccer player accumulated body fat during off-season period. Therefore, it was important for the players to maintain certain physical activity levels and suitable diets during off-season.

2.2.1.2.4 Body mass index (BMI) of soccer players

The relation between height and body mass is equally important due to the fact that modern football implies duel play, jump head play, fast activities (alternating offense and defense), all of which are linked to efficient realization and the obligatory playing time during the entire match (Hazir, 2010; Matkovic, et al., 2003; Reilly & Williams, 2003).

Soccer is an aerobic-anaerobic (stop-go) type of sport with alternate phases of high load as sprints, fast zigzag running, jumps and sudden stops. Practically in all activities a player carries his mass, moves it against the force of gravity so that each excess of body fat represents an overload which additionally burdens the energy mechanisms and makes the execution of a whole series of activities, especially the jumps and sprints, more difficult (Matkovic, et al., 2003).

Study by (Ostojic, 2003) has recorded body fat percentage levels over the course of an entire season which includes values at pre-season, start of the season, mid-season and at the end of the season. The results of this study found that the estimated body fat percentage at the end of the season 9.6 ± 2.5

% was significantly lower than levels recorded at preseason $11.5 \pm 2.1\%$, the start of the season $10.9 \pm 2.4\%$, as well as at the mid-season period $10.2 \pm 2.9\%$.

There were however, no significant differences between measurements performed during the season. The main reason for lower values at the end of the season is as a result of both the effect of competition as well as the continued intensity of training that occurs during the playing season. (Ostojic & Zivanic, 2001) have also demonstrated that in addition to obvious benefits associated with decreased levels of body fat percentage for soccer players, the main benefits experienced by is improvements in sprint times, which continue to decrease as the intensity of the season increases.

2.2.1.2.5 Anthropometric and personal characteristics review in previous soccer studies

The literature reviewed in the following Tab. 3 includes studies published from the recent years to the present, which tested and reported anthropometric measurements of elite and professional soccer players. These data were compiled with the anthropometrics data that was collected in this study from professional soccer players in the Bundesliga to contribute to the final soccer specific table of updated normative values.

Tab. 3: Comparison between anthropometric variables assessed in this study with reported values from previous studies in elite and professional soccer players (mean \pm SD).

References	Nationality	Level	n	Age	Height	Weight	BMI*
				(year)	(m)	(kg)	(kg m ⁻²)
(Aziz et al., 2000)	Singaporean	Professional	23	21.9 \pm 3.6	1.75 \pm 0.06	65.5 \pm 6.1	21.39
(Rienzi et al., 2000)	South American	Elite	11	26.1 \pm 4.0	1.77 \pm 0.06	76.4 \pm 7.0	24.39
(Al-Hazzaa, et al., 2001)	Saudi Arabian	Elite	154	25.2 \pm 3.3	1.77 \pm 0.06	73.1 \pm 6.8	23.33
(Casajus, 2001)	Spanish	Professional	15	26.3 \pm 3.1	1.80 \pm 0.07	78.5 \pm 6.4	24.23
(Cometti et al., 2001)	French	Elite	29	26.1 \pm 4.3	1.80 \pm 0.04	74.5 \pm 6.2	22.99
(Strudwick, et al., 2002)	English	Elite	19	22.0 \pm 2.0	1.77 \pm 0.06	77.9 \pm 8.9	24.87
(Matkovic, et al., 2003)	Croatian	Elite	57	23.2 \pm 3.5	1.81 \pm 0.06	77.6 \pm 5.7	23.69
(Ostojic, 2003)	Serbian	Elite	30	23.5 \pm 3.1	1.83 \pm 6.0	76.8 \pm 6.1	22.93
(Mohr, et al., 2003)	Italian	Professional	18	26.4 \pm 0.9	1.80 \pm 0.01	75.4 \pm 1.5	23.27
(Wisloff et al., 2004)	Norwegian	Elite	17	25.8 \pm 2.9	1.77 \pm 4.1	76.5 \pm 7.6	24.42
(Bloomfield, et al., 2005)	English	Professional	578	26.3 \pm 4.8	1.81 \pm 0.06	75.3 \pm 7.3	22.90
(Bloomfield, et al., 2005)	German	Professional	480	26.6 \pm 4.4	1.83 \pm 0.06	77.5 \pm 6.4	23.20
(Bloomfield, et al., 2005)	Italian	Professional	499	26.4 \pm 4.4	1.81 \pm 0.05	74.3 \pm 5.4	22.80
(Bloomfield, et al., 2005)	Spanish	Professional	528	26.5 \pm 4.0	1.80 \pm 0.06	75 \pm 5.6	23.10
(Bloomfield, et al., 2005)	Europeans	Professional Total	2085	26.4 \pm 4.4	1.81 \pm 0.06	75.5 \pm 6.3	23.00
(Kalapotharakos et al., 2006)	Greek	Elite	19	26.0 \pm 4.0	1.80 \pm 5.0	78.0 \pm 4.5	24.07
(Reinhold, 2008)	German	Professional	53	24.9 \pm 4.3	1.83 \pm 7.0	78.6 \pm 7.1	23.47
(Dellal et al., 2008)	French	Elite	10	26.0 \pm 2.9	1.81 \pm 5.9	78.3 \pm 4.4	23.90
(Hazir, 2010)	Turkish	Elite	161	25.7 \pm 3.73	1.78 \pm 5.66	76.1 \pm 6.18	24.02
(Hazir, 2010)	Turkish	Professional	144	24.1 \pm 4.27	1.78 \pm 5.90	73.9 \pm 6.34	23.32
(Hoppe et al., 2012)	German	Professional	11	23.8 \pm 3.0	1.79 \pm 8.9	76.6 \pm 8.6	23.91
(Silva et al., 2012)	Portuguese	Professional	13	25.7 \pm 4.6	1.78 \pm 5.7	76.5 \pm 9.2	24.14
(Freiwald & Baumgart, 2012)	German	Professional	14	24 \pm 3.95	1.82 \pm 0.04	80.60 \pm 6.38	24.18
Present study	German	Professional	14	24.57 \pm 4.33	1.85 \pm 0.07	83.86 \pm 8.5	24.50

* BMI based on mean values of height and body weight

According to previous studies in Tab. 3, the anthropometric profile in elite and professional soccer players reported range of average age between 21.9 ± 3.6 to 26.5 ± 4.0 years, height 1.75 ± 0.06 to 1.83 ± 6.0 m, body weight 65.5 ± 6.1 to 78.6 ± 7.1 kg and (BMI) between 21.39 to 24.87 kg m^{-2} .

The anthropometric profiles difference between elite and professional soccer players of previous studies may be caused by several reasons such as morphological factors of players, strategies for talent selection and the system nation leagues in their federations. For example, the study by (Bloomfield, et al., 2005) indicates that top leagues in Spain and Italy had a shorter and lighter players compared to those in England and Germany, especially in midfield and forward positions.

Generally, anthropometric profiles of elite and professional soccer players around different leagues don't wide to each others and not significantly differ from the normal population as for their morphological characteristics body height and body weight. The difference between them in (BMI) is result of a specific training process and related to the body fat between them.

2.2.1.3 Anthropometric and personal characteristics of rugby players

Descriptive anthropometric characteristics offer information that can be used to analysis the size, proportionality and body composition of rugby players. This players profile can be used in rugby union sport to design an exercise and nutrition interventions for improving health and performance, for talent identification, analysis specific physical characteristics to the sport, work rate, evolutionary trends, injuries and comparisons between countries (Holway & Garavaglia, 2009).

Because of the game physical requirements and its relatively recent development in 1995, the size characteristic of rugby players has increased substantially. Most likely due to a combination of factors such as higher selection pressures and improved talent identification, nutritional and training (Olds, 2001).

With the evolution of rugby union sport development, factors such as sport training, greater access to sport science, full-time training staff and coaches and desire for more physical players. For these factors, there is a need to greater player development and a marked increase in player size such as height, body weight and body mass index.

The differences between specific positions in these anthropometrical measures demonstrate the heterogeneous nature of contact team sport players such as rugby union. A high degree of variation in the size of players exists due to each positions unique role and requirements within competition (Holway & Garavaglia, 2009; Reilly, 1997).

2.2.1.3.1 Age of rugby players

There are lack researches that described the age difference between countries or play levels in top elite and professional rugby players. (Nicholas, 1997) in descriptive anthropometric and physiological study for rugby players, demonstrate that the age ranges mean between 21 to 28.5 years for 15 teams from United States, South Africa, Germany and England, also reported age mean for forward players between 23 to 30 years and for back players between 22 to 26 years.

The study of (Brick & O'Donoghue, 2005) reported age mean of 28.8 ± 3.9 years for forward players and 21.2 ± 2.2 for back players, as same as study of (Kuhn, 2005) reported age mean of 23 ± 3.0 years for forward players and 22.4 ± 3.5 years for back players in rugby union team, who competed in highest national league in Germany.

The optimal peak playing age for elite rugby players, at which they perform their best is said to be in the range of 24-27 years. In this study, the mean age of the rugby players was 24 ± 3.94 years, and relatively confirmed the results of (Appleby et al., 2011) who reported mean age of 24.4 ± 3.4 years for rugby players.

2.2.1.3.2 Height of rugby players

Height as an anthropometrical factor is useful in sports involving jumping, while body mass is useful in contact sports such as rugby union and American football. Height differences among the various positional groups in rugby union are unclear (Duthie, et al., 2003). Previous studies have demonstrated that county and international forwards and backs have similar height (Olds, 2001).

On the other hand, others have shown that forwards are markedly taller than backs of the same level (Nicholas, 1997; Nicholas & Baker, 1995; Quarrie et al., 1996). It would be fair to assume that elite level rugby players have greater height than non-elite players, since height is an essential at higher levels of performance, especially in the forwards.

In contrast, the Bledisloe cup study (1972 to 2004) shows that forwards have become slightly shorter, whereas backline players have become taller. It may be reasoned that the decrease in height of the forwards associated with the introduction of the law permitting line-out³ jumpers to be supported in the line-out. This law allows good lifters to overcome slight disadvantages in the height of the jumper. This law also introduced new requirements for successful line-out play, such as visual acuity, timing, and the ability to coordinate between the jumpers, lifters and hooker throwing in the ball (Quarrie & Hopkins, 2007). These differences in height factor are all based on the positional roles and requirements of the players.

2.2.1.3.3 Body weight of rugby players

There has been a significant change in the body weight of elite rugby players over the past 20 years, with the increase being greater than what would be expected for the normal upward trend in the population (Olds, 2001). Consequently, literature older than ten years may have limited application to current day rugby players (Duthie, et al., 2003), especially with increased professionalism and the physical demand of top professional level rugby union constantly progressing.

³ Line-out: It is a way to restart play, after the ball has gone into touch, with a throw-in between two lines of players (www.ibr.com).

The Bledisloe cup study (1972 to 2004) showed that, body weight of both forward and back players increased significantly 7.1% and 12.3%, respectively. The most successful teams had greater mass in the forwards. A greater body mass confers an advantage in the contact phases of the sport, because of the great momentum players are able to generate (Quarrie & Hopkins, 2007).

An increased focus on weight training and usage of nutritional supplements may also have contributed to the increase changes in body mass (Duthie, et al., 2003). It is logical to assume that the accelerated increase in body mass over the past 30 years can be attributed to better knowledge and implementation of programmes involving nutrition, supplements and resistance training.

2.2.1.3.4 Body mass index (BMI) of rugby players

(Olds, 2001) used historical data to follow the evolution of physique in male rugby players from 1905 to 1999. It was shown that the body mass index had increased at a rate three to four times faster in rugby players during the last 25-years compared to the rest of the century.

The body mass index (BMI, $\text{kg}\cdot\text{m}^{-2}$) was calculated as the body mass (kg) divided by the squared height (m), and it is primarily an indicator of heaviness and only indirectly of body fat. Study of (Duthie, et al., 2003) stated ranges body fat of elite rugby players from about 8 to 17%. Forward rugby players generally have a greater percentage of body fat than back players, and it might also be said that as the proficiency level increases, the average percentage of body fat decreases. Body fat does not contribute to the generation of muscle power and therefore excessive amounts of body fat will reduce from sprinting ability.

Alternatively, earlier data on first-class players demonstrated that forwards ($11.1 \pm 1.2\%$) had a lower percentage body fat than their second-class equivalents ($13.3 \pm 1.0\%$) (Duthie, et al., 2003). The differences in percentage body fat may reflect the higher training levels and more favorable dietary practices of elite players. The lower body fat of the backs ($10.0 \pm 2.3\%$) (Carlson et al., 1994) may also reflect the higher speed requirements of these players. While additional body fat may serve as a protective buffer in contact situations, it is a

disadvantage in sprinting and running activities. Given the different demands for forwards and backs, it is not surprising that body fat differs between these positions (Duthie, et al., 2003).

2.2.1.3.5 Anthropometric and personal characteristics review in previous rugby studies

Anthropometric evaluation of rugby players is essential to assist talent selection, guide training, monitor seasonal variations and quantify the evolving demands of the game. Scientific data for rugby players are relatively limited, thus the descriptive anthropometrics data in the following Tab. 4 providing normative data on anthropometric characteristics of elite and professional rugby players.

In respect to compare data with other countries, the descriptive anthropometrics profile data were compared only with nations from other countries, but not with studies, which profiled data for player positions as forwards and backs in rugby sport. According to previous studies in the following table, the anthropometric profile in elite and professional rugby players reported range of average age between 22.7 ± 3.2 to 27.61 ± 4.2 years, height 1.77 ± 5.45 to 1.88 ± 7.1 m, body weight 85.5 ± 9.61 to 107.1 ± 10.1 kg and (BMI) between 27.77 ± 2.33 $\text{kg}\cdot\text{m}^{-2}$.

Tab. 4: Comparison between anthropometric variables assessed in this study with reported values from previous studies for elite and professional rugby players (mean \pm SD)

References	Nationality	Level	n	Age	Height	Weight	BMI*
				(year)	(m)	(kg)	(kg m ⁻²)
(Carlson, et al., 1994)	Americans	Elite	33	26.3 \pm 2.54	1.83 \pm 7.47	90.6 \pm 12.31	27.05
(Quarrie, et al., 1995)	New Zealander	Senior A (F)	50	22.7	1.86	98.5	28.47
(Quarrie, et al., 1995)	New Zealander	Senior A (B)	44	21.9	1.78	81.8	25.82
(Nicholas & Baker, 1995)	English	First Class (F)	15	22.7	1.86 \pm 2.0	97.3 \pm 1.9	28.12
(Nicholas & Baker, 1995)	English	First Class (B)	15	21.9	1.78 \pm 1.7	79.3 \pm 1.8	25.03
(Tong & Mayes, 1997)	Wales	Professional (F)	21	25.6 \pm 3.3	1.87 \pm 0.09	105.1 \pm 9.3	30.06
(Tong & Mayes, 1997)	Wales	Professional (B)	18	24.6 \pm 2.7	1.76 \pm 0.03	82.6 \pm 6.6	26.67
(Quarrie & Wilson, 2000)	New Zealander	Professional	56	23.2 \pm 3.1	1.83 \pm 8.0	96.9 \pm 9.8	28.93
(Babic et al., 2001)	Croatian-Slovenian	Professional	111	25.6 \pm 6.0	1.80	87.85	27.11
(Olds, 2001)	---	Elite 1905-1974	58	25.6 \pm 3.5	1.80	87.8	26.20
(Olds, 2001)	---	Elite 1975-1999	1362	25.6 \pm 3.5	1.84	95.1	28.60
(Gamble, 2004)	English	Professional	35	27.61 \pm 4.20	1.85 \pm 7.27	98.61 \pm 13.74	28.81
(Kuhn, 2005)	German	Elite	17	22.7 \pm 3.2	1.84 \pm 6.5	88.2 \pm 13.7	26.05
(Quarrie & Hopkins, 2007)	New Zealander	Elite (F) 1995	---	---	1.91 \pm 0.7	102.3 \pm 1.2	28.04
(Quarrie & Hopkins, 2007)	New Zealander	Elite (B) 1995	---	---	1.80 \pm 1.1	83.4 \pm 2.1	25.74
(Quarrie & Hopkins, 2007)	New Zealander	Elite (F) 2004	---	---	1.90 \pm 1.0	111.1 \pm 2.9	30.78
(Quarrie & Hopkins, 2007)	New Zealander	Elite (B) 2004	---	---	1.83 \pm 0.8	95.7 \pm 2.3	28.58
(Wu et al., 2007)	Taiwan	Elite	10	24.50 \pm 1.08	1.77 \pm 5.45	85.50 \pm 9.61	27.29
(Holway & Garavaglia, 2009)	Argentinean	Professional	133	24.3 \pm 3.6	1.79 \pm 7.3	89.5 \pm 13.2	27.93
(Argus et al., 2009)	New Zealander	Professional	32	24.4 \pm 2.7	1.85 \pm 6.2	104 \pm 11.2	30.39
(Wheeler & Sayers, 2010)	Australian	Professional	8	23.0 \pm 4.0	1.83 \pm 4.0	98.0 \pm 11.0	29.26
(Argus et al., 2011)	New Zealander	Elite	18	23.8 \pm 2.2	1.86 \pm 6.0	103.8 \pm 10.6	30.00
(Austin et al., 2011)	Australian	Professional	20	23.8 \pm 2.3	1.82 \pm 4.0	101 \pm 7.0	30.49
(Crewther et al., 2011)	New Zealander	Professional	30	25.7 \pm 2.5	1.88 \pm 7.1	107.1 \pm 10.1	30.30
(Pogliaghi et al., 2011)	Italian	Elite	123	25	1.87	99.5	28.45
(Sedeaud et al., 2012)	Rugby World Cup	Elite 1987 (F)	111	26.79	1.88	102.42	29.17
(Sedeaud, et al., 2012)	Rugby World Cup	Elite 2007 (F)	203	27.08	1.88	109.05	30.85
(Sedeaud, et al., 2012)	Rugby World Cup	Elite 1987 (B)	95	25.33	1.80	82.96	25.50
(Sedeaud, et al., 2012)	Rugby World Cup	Elite 2007 (B)	171	25.41	1.82	89.64	27.09
Present study	German	Elite	14	24 \pm 3.94	1.81 \pm 0.05	91.05 \pm 12.16	27.77 \pm 2.33

* BMI based on mean values of height and body weight; (F) = Forwards; (B) = Backs; --- = No available data

In general, rugby players in current study observed in normal height mean and similar to elite and professional players from other countries, who reported range mean from 1.77 ± 5.45 to 1.88 ± 7.1 m, body weight 85.5 ± 9.61 to 107.1 ± 10.1 kg and (BMI) 25.03 to 30.85 $\text{kg}\cdot\text{m}^{-2}$.

The collects data in Tab. 4, reflected the changes in body size for rugby players during recent years, and indicated that rugby players became heavier in body weight. (Olds, 2001) documented changes in the body size of rugby players in the twentieth century, and reported that increases in the mass of male rugby players were more rapid than increases in the mass of males in the general population. Some of the body weight changes, which observed in Tab. 4, lend support to this conception.

Although the observation of the physiques of rugby players reflect the specific demands of the sport, it has been remarked upon previously in Bledisloe Cup rugby union from 1972 to 2004 (Quarrie & Hopkins, 2007) and world cup rugby players (Sedeaud, et al., 2012), that quick increase in body weight observed subsequent to the introduction of professionalism was probably the result of selection pressure towards increased body weight. However, no significant increase in height observed during recent years in Tab. 4 with agreement of previous studies of (Olds, 2001; Quarrie & Hopkins, 2007; Sedeaud, et al., 2012).

2.2.2 Speed

Speed and agility are necessary abilities, which can affect performance in a variety of sports. These abilities are related and depend on the player's muscular strength. Integrating speed and agility training into the training plan and changing specific training variables can optimize sport performance capacity. Therefore, understanding factors and variables, which affect speed and agility enables the coaches to develop sport specific training plans and programmes that maximize sport performance (Bompa & Haff, 2009).

2.2.2.1 Definition and structure of speed

2.2.2.1.1 Definition of speed

Speed is the rate of motion or the rate of change of position. It is expressed as distance moved (d) per unit of time (t). Speed is a scalar quantity with dimensions distance / time. This definition is not enough to describe the complex concept of speed.

In sport generally speed defined as an ability to move as fast as possible over a specific distance. Speed is the displacement per unit time and is typically quantified as the time taken to cover a fixed distance (Baechle & Earle, 2008). (Bompa & Haff, 2009; Dick, 2007) have defined speed in training theory as the capacity of moving a part of body or the whole body to cover distance with the greatest possible velocity.

In context of competition, (Bompa & Claro, 2009) defined speed as the capacity to move quickly as fast as possible in the field according to the game conditions and placement of the opposing players, and described that the term of speed includes three element components: reaction time, stride frequency per second and the speed to cover a given distance. Thus the ability to be quick and react is important elements of speed that are needed for every player in the game.

(Steinhöfer, 2003) has defined also speed, as a conditional coordinate that determined performance requirement to respond stimulations or signals in the shortest possible time, and / or cyclic or acyclic movements at low resistance that performed at the highest possible speed.

There are many references that defined the term of „speed“ of different view points. In many cases, the term of speed in references has been defined as the ability to sprint. In context of athletics (Clark et al., 2010) defined speed as the “rate of performance” of an activity, which can refer to any movement or action and especially for sprinter. Acyclic and cyclic could be described as forms of speed, which are characteristic of a large number of field team sports such as soccer and rugby union, but this description isn't enough as a clear definition of both speed forms.

Therefore, (Schnabel et al., 2003) have described the difference between cyclic and acyclic movements. In their view, this term indicates that,

- „acyclic and cyclic movement activities to be obtained, requires high values of speed, as well as
- reaction processes that occur in the shortest time

(e.g. Sprinting, running with fast turning, quick jump or push off and respond to a technical-tactical task quickly and to solve them quickly)“.

(Clark, et al., 2010) adds in his definition to the meaning of speed, that is a conclusion of reactive ability, rapid force development, rapid force application and effective movement technique. Generally, when the force demands of an activity increase, the velocity output of the movement decreases. According to the review of references of (Bompa & Haff, 2009; Clark, et al., 2010; Schnabel, et al., 2003) who defined the speed of different standard points in theoretical and practical sport training. Structure of important speed activities during field team sports in current study will be discussed in the next section.

2.2.2.1.2 Structure of speed

Speed of movement is important to sports performance and in many sports such as soccer and rugby union, is the basis for player selection and successes in competitions. Thus, sports performance may depend more on the players to accelerate quickly and change their direction in game situations than to maintain speed over a longer distance. While sprint speed in a straight line (linear sprint) and agility (non linear) or change of direction sprint are related, they are clearly different skills and every each of them depends on many factors.

(Little & Williams, 2005) have described the high speed actions during competition, they stated that high speed action can be categorized into actions requiring acceleration, maximal speed, or agility. Acceleration is the rate of change in velocity that allows a player to reach maximum velocity in a minimum amount of time. Maximum speed is the maximal velocity at which a player can sprint. Agility is often recognized as the ability to change direction and start and stop quickly.

Therefore, acceleration, deceleration and change of direction movements are important specific qualities in field games. Due to the variable nature of match play and high speed movements activities, may be initiated from a variety of starting positions. Multidirectional acceleration from both standing and moving starts must therefore be provided for in sport specific agility and speed training design. In this view, speed and agility in field team sports such as soccer and rugby union occurs in response to game situations (Young et al., 2001).

From this viewpoint, practice related strategies that are specific to the sport have application in speed and agility training. According to (Little & Williams, 2005; Schnabel, et al., 2003; Young, et al., 2001) who explained the speed movements categories as running in linear and non-linear sprint. The understanding of multidirectional speed and agility movements are important and useful in field team sports in current study.

1. Linear Sprint

The most important component of sports specific speed training is the development of linear sprint. Linear sprint is when a player starts from a stationary position and begins sprinting explosively as fast as possible in a straight line. Acceleration and deceleration are important factors in this movement of speed and for every sport is repeated multiple times throughout competitions.

Acceleration is the ability to increase movement speed in a short time and determines sprint performance abilities over short distances (e.g., 5 m and 10 m) and usually assessed as a velocity (e.g., m/s) or as a unit of time (e.g., seconds or minutes). The ability of acceleration is different between players for a variety of sports and players positions in the field (Bompa & Haff, 2009).

High rate of acceleration are reached in the first 8 to 10 steps, which taken by player, when running at linear sprint. Close to 75 percent of maximum running velocity is established within the first 10 yards (9 m). Maximum running speed at the end of linear sprint phase is approximately reached within 4 to 5 seconds. Player who ensures a proper transition to top speed, quick running steps should

gradually increase in length until full stride length is achieved (Brown & Ferrigno, 2005).

(Carling, et al., 2009) recommended in a competitive context that, players must react quickly to an external stimulus and accelerate up to top speed and maintain it for as long as necessary, which timing and anticipation are important factors in starting of the movement. Maximum speed running may not be reached until about 40-60 m before gradually declining. Therefore, acceleration at 5 m, 10 m and velocity (to 30-40 m) is the best distances, which measured using timing gates. Sprints more than 30 m in length, players may consider that maximum speed is not often achieved in their competition and may not take this component of performance into consideration when testing players.

However, players often start sprints when already moving at moderate speeds and maximum speed may be achieved more often than distance and time would otherwise predict (Little & Williams, 2005), and therefore it is useful to measure this component of sprint tests.

2. Non-Linear Sprint

Non-linear sprint is when a player starts from a stationary position and begins sprinting explosively in a non straight line. This description isn't enough, thus in many sports the non linear sprint known as the ability of players, who can sprint quickly and stop suddenly to turn his body in other direction in short time. This movement is important in sports as soccer and rugby union, which players need to change their directions quickly in many situations in the game. This multidirectional movement in many literatures called agility or change of direction.

Agility refers to the ability to change direction quickly or to alter the position of the body in space without loss of balance. It has many component factors, including elements of strength, balance, coordination and speed of movement. Agility assessment is generally confined to tests of physical components even though this element of performance also includes cognitive components such as

visual scanning techniques, visual-scanning speed and anticipation (Sheppard & Young, 2006).

In more recent literatures, some authors have defined agility to include whole body change of direction as well as rapid movement and direction change of limbs (Baechle & Earle, 2008; Bompa & Haff, 2009). In the context of field team sports, agility therefore includes not only change of direction abilities but also perception and decision making. The limited common variance frequently reported between change of direction and speed tests indicate that change of direction performance is relatively independent of straight line sprint performance (Gamble, 2010; Little & Williams, 2005; Young, et al., 2001).

In any case, change of direction abilities are a foundation of agility performance. As such, tests of change of direction performance do provide important information, which confirms their inclusion in any battery of tests for field team sports. Agility tests that are more specific to the individual demands of various field sports have also been developed and are covered later in this chapter.

2.2.2.2 Speed characteristics of soccer players

Speed as an important component in soccer game. Players during match play must be able to accelerate to meet the physical, tactical and technical components of the game. In addition, soccer players require during match play to run successfully with the ball at their feet with high speeds, while at the same time avoiding tacklers of opposite team. For this reason, this section demonstrates the benefits of speed in soccer to understand the laws of its development.

2.2.2.2.1 Linear sprint in soccer

Soccer is a physically demanding sport requiring the repetition of many diverse activities such as jogging, running and sprinting. Time motion match analysis studies have also demonstrated that soccer requires participants to repeatedly produce maximal or near maximal more actions of short duration with brief recovery periods (Wisloff et al., 1998).

Concerning speed performance, (Silvestre et al., 2006) suggests that the ability for acceleration is an important factor in the success for soccer players in game situations, where the need to reach the ball first or to be in place for the development of a play is essential. Speed is a very important aspect for ball follow, gaining defense advantage to clear a danger play and or generating opportunities to score goals.

(Cometti, et al., 2001) clarifies this importance of acceleration during sprint and confirmed that short sprinting performance may mirror actual game situations at high level and could be an important determinant of match winning actions. As well as in this line, (Rienzi, et al., 2000) have investigated South American international soccer players, and recorded that they perform different actions with and without the ball during a game on average of 1431. In addition, have observed that forwards players sprinted a greater distance than defensive players 557 ± 142 and 231 ± 142 m. Based on this data, it seems that a players profile is dependent upon the type of competition and the playing position.

(Stolen, et al., 2005) have compared soccer players results from recent studies in their study, and reported that each player can perform about 1000-1400 different actions per game, and recorded that change mean of these actions occur every 4-6 sec.

Players very rarely cover distances over 25 m in a game, but speed and the ability to accelerate can decide important outcomes of the game. As soccer players are required to repeat fast bursts of speed, a high anaerobic capacity is essential in order to play at a high tempo (Bangsbo, 1994a, 1994c).

The sprints a soccer player makes during match play are mostly 10-25 m in length, or 3-5 s in duration and as such testing for sprint ability usually takes the form of a 10 m, 20 m or 30 m sprint (Strudwick, et al., 2002). However, explosive acceleration over 5 m may also be of great importance when considering soccer performance.

Players have to possess the ability to accelerate to meet the components requirements of the soccer game. Sprinting constitutes 1-11% of total distance

covered during match play with a sprint bout occurring every 90 seconds and lasting 2-4 seconds (Bangsbo, et al., 1991; Reilly & Gilbourne, 2003). Also, (Stolen, et al., 2005) in their comparable study reported that 96% of all sprints are shorter than 30 meters and 49% are shorter than 10 m.

(Bradley et al., 2009) distinguished the match activity profiles of elite soccer players, who competed in English FA Premier League. Player activities were coded into the following six categories, which presented in Tab. 5, the authors have consisted high-intensity running of running, high-speed running and sprinting ($\geq 14.4 \text{ km.h}^{-1}$). Very high-intensity running consisted of high-speed running and sprinting ($\geq 19.8 \text{ km.h}^{-1}$).

Tab. 5: Match activities in elite soccer players (Bradley, et al., 2009)

Categories	Activities intensity
Standing	0 - 0.6 km.h^{-1}
Walking	0.7 - 7.1 km.h^{-1}
Jogging	7.2 - 14.3 km.h^{-1}
Running	14.4 - 19.7 km.h^{-1}
High-speed running	19.8 - 25.1 km.h^{-1}
Sprinting	$\geq 25.2 \text{ km.h}^{-1}$

In addition, authors have examined the differences of the match activities between playing position, whose categories as central defenders, full-backs, central midfielders, wide midfielders and attackers in Tab. 6. In this study, participated Twenty-eight elite soccer players and were analyzed during the competitive season ($n=370$), using a multi-camera computerized tracking system.

Tab. 6: Comparison covered distances of match performance activities between positions in elite soccer players (mean \pm SD) (Bradley, et al., 2009)

Player positions	n	High-intensity running (m)	Very high-intensity running (m)	Sprinting (m)
Central defenders	92	1834 \pm 256	603 \pm 132	152 \pm 50
Full-backs	84	2605 \pm 387	984 \pm 195	287 \pm 98 ^b
Central midfielders	80	2825 \pm 473	927 \pm 245	204 \pm 89
Wide midfielders	52	3138 \pm 565 ^a	1214 \pm 251 ^a	346 \pm 115 ^b
Attackers	62	2341 \pm 575	955 \pm 239	264 \pm 87

^a Different from all other playing positions ($p < 0.05$); ^b Different from central defenders, central midfielders and attackers ($p < 0.01$)

The results in Tab. 6 demonstrated that wide midfielders covered a greater distance in high-intensity running than all other positions and central defenders was less than all other positions ($p < 0.01$). Wide midfielders and full-backs covered a greater distance when sprinting than all other positions ($p < 0.01$).

In the same line for examination match performance activities in soccer players. (Verheijen, 2000) has been demonstrated the covered total number of match activities in five top levels soccer league and the positions of soccer players in Netherlands Fig. 3.

	Total number of "runs"	Walking	Jogging	Running	Sprinting	Sideways	Walking backwards	Jogging backwards	In Possession
Defenders									
Professional league	1557	662	335	83	162	110	158	19	28
Top class amateurs	1323	581	311	50	111	93	124	21	32
2nd class amateurs	1171	512	320	41	62	63	103	17	33
5th class amateurs	993	474	289	21	84	56	71	13	21
Under 18 juniors	1458	686	347	72	101	82	120	18	32
Midfielders									
Professional league	1570	539	503	117	127	91	139	17	37
Top class amateurs	1345	520	410	83	92	79	106	22	33
2nd class amateurs	1195	519	352	54	69	69	86	20	26
5th class amateurs	1036	502	312	37	51	48	54	15	17
Under 18 juniors	1393	517	466	88	94	76	100	21	31
Attackers									
Professional league	1473	500	397	90	183	121	144	23	15
Top class amateurs	1252	449	386	56	127	84	116	17	17
2nd class amateurs	1164	461	365	60	99	60	91	17	11
5th class amateurs	1076	492	329	39	66	57	70	11	12
Under 18 juniors	1399	537	403	72	134	102	116	19	16

Fig. 3: Comparison total number of match activities between play levels and positions in Netherlands soccer player leagues (Verheijen, 2000), page 18.

The comparisons data in league levels and player positions of soccer in Netherlands reported that, players in professional league covered a greater distance than all others levels. However, not surprising that covered total number running of match activities in professional player positions observed also greater than all other levels. Defenders players in professional league have recorded value of total sprinting about 3.38 times of 5th class defenders player. Midfielders and attackers player in professional league have recorded 2.49 and

2.77 times of players in 5th class players, respectively. The difference values in total number of runs activities between professional league players and 5th class players are due to many factors such as age, experience training and the physical characteristics profile.

According to (Bangsbo, 1994a; Strudwick, et al., 2002), who indicated that the 10-25 m sprint is the most distance during match-play and recommended that testing for sprint ability usually takes the form of a 10 m and 30 m. Acceleration and speed tests were carried out with the use of timing gates placed at different distances. Therefore, in this study explosive sprint, acceleration and maximum sprints over 5 m, 10 m and 30 m were assessed as a most relevant to the demands in the soccer game.

2.2.2.2.2 Non-Linear sprint in soccer

Agility could describe a soccer player who rapidly accelerates or decelerates in a straight line to avoid an opponent, as this action is not pre planned, would be in response to the movements of the opposing player (stimuli) and is an open skill (Sheppard & Young, 2006). The activity pattern during an elite soccer match is forceful and explosive and includes rapid turns, accelerations, changing direction quickly, tackling, side-stepping and game specific skills (Bangsbo, 1994a; Tumilty, 1993).

The ability to change direction (turning) is a key factor in developing elite soccer players and it is the strongest predictor for talent identification (Reilly & Gilbourne, 2003). During soccer game, players in top level perform about 50 turns and comprising sustained forceful contractions to maintain balance and control of the ball against defensive pressure (Stolen, et al., 2005). (Reilly & Williams, 2003) stated that each game typically involves about 1000 changes of activity by each individual in the course of play, and each change requires sudden acceleration or deceleration of the body or an alteration in the direction of motion.

Thus, the turning ability has previously been related with the velocity of movement in soccer. Players who are traveling at $\leq 2 \text{ m}\cdot\text{s}^{-1}$ appear to be able to

turn in a sector $\leq 240^\circ$ to during movement with respect to the direction that they are moving in. However, the scope for direction change decreases as velocity increases with players restricted to a sector of $\leq 80^\circ$ of potential movement when moving at speeds $\geq 5 \text{ m}\cdot\text{s}^{-1}$. This method was used to analyse the pre-goal phases of the 1992 European Nations Cup final between Denmark and Germany (Grehaig et al., 1997).

According to study of (Dawson, 2003), the large majority of sprints performed in a soccer match usually occur over short distances involving at least one change of direction, and it is often over these short distances that goals are scored and matches won or lost. The rapid pace of elite contemporary soccer requires players to possess good agility, as they are required to be able to run successfully with the ball at their feet at high speeds while simultaneously avoiding tacklers.

Agility requirements of soccer can be enlightened by the volume and type of deceleration and turning movements, which are performed during competitive matches. The movements within or between which turns are performed can be analyzed by exploring temporal relationships between movements performed before and after turns. For this reason, Bloomfield et al. (2007) addressed the agility requirements of the game through analyzing direction of movement or the frequency of turns within movements. The authors reported that the players performed the equivalent of 726 ± 203 turns during the match; 609 ± 193 of these being of 0° to 90° to the left or right and involved in the equivalent of 111 ± 77 on the ball movement activities per match.

The analysis of deceleration and turning movements in contemporary professional soccer suggests that these actions are a common and extremely important part of the modern game and there is a particular need for developing specific deceleration and turning exercises in conditioning training. (Bloomfield, et al., 2007) provided a detailed time–motion analysis technique, which includes details of turning performed by players. The classification system has been used to investigate the movement performance by English FA Premier League soccer

players in terms of frequency, duration and percentage time for different locomotive movements, movement in different directions and movement of different intensities. The following table presents the direction movements data, which traveled within the analyses motion and the comparison of the percentage of each purposeful movement in any of the other directions between player positions, which classified as defender, midfielder and striker.

Tab. 7: Comparison % time of directions movements that travelled within purposeful movement by player positions (mean \pm SD) (Bloomfield, et al., 2007)

Directions movements	Positions			
	Defender (n = 19)	Midfielder (n = 18)	Striker (n = 18)	All (n = 55)
Directly forwards	45.3 \pm 7.7	54.1 \pm 7.5	46.9 \pm 10.1	48.7 \pm 9.2
Directly backwards	10.1 \pm 3.5*	5.2 \pm 2.8	5.6 \pm 2.7	7.0 \pm 3.7
Lateral left	6.5 \pm 2.9*	3.4 \pm 1.4	3.7 \pm 1.6	4.5 \pm 2.5
Lateral right	5.0 \pm 3.0 [‡]	3.2 \pm 1.7 [‡]	3.5 \pm 1.6	3.9 \pm 2.3
Forward diagonal left	4.5 \pm 2.2	4.9 \pm 2.0	4.5 \pm 1.7	4.6 \pm 1.9
Forward diagonal right	5.1 \pm 2.9	4.4 \pm 2.7	5.4 \pm 2.2	5.0 \pm 2.6

Follow up Mann Whitney U tests: * significantly different to both other positions; [‡] pair of positions annotated is significantly different

The results in Tab. 7 demonstrated that players performed a total of 727 \pm 203 turns during match-play, and the most movement is directly forwards. Player positions had a significant influence on the total number of turns that performed with midfielders and performing significantly fewer turns, which defenders and strikers ($p < 0.05$). In the following table, the authors have analyzed also the frequency of turns within match play and the number of turns performed per purposeful movement that categorized into four angel grades, which are mostly performed in soccer game.

Tab. 8: Comparison frequency of turning that travelled within a match performed by player positions (mean \pm SD) (Bloomfield, et al., 2007)

Directions movements	Positions			
	Defender (n = 19)	Midfielder (n = 18)	Striker (n = 18)	All (n = 55)
0-90° right	344.3 \pm 91.0	248.3 \pm 97.3*	323.7 \pm 105.1	305.8 \pm 104.7
0-90° left	364.3 \pm 88.4	243.0 \pm 93.5*	302.2 \pm 81.2	303.2 \pm 99.3
90-180° right	43.0 \pm 16.8	49.3 \pm 25.0	43.3 \pm 15.6	45.2 \pm 19.4
90-180° left	49.3 \pm 24.4	47.0 \pm 24.5	51.5 \pm 13.9	49.3 \pm 20.1
180-270° right	2.3 \pm 3.0	4.7 \pm 3.9	2.5 \pm 4.2	3.2 \pm 3.8
180-270° left	2.0 \pm 2.9	3.0 \pm 4.7	2.2 \pm 3.6	2.4 \pm 3.8
270-360° right	0.0 \pm 0.0	0.7 \pm 1.9	1.3 \pm 2.5	0.7 \pm 1.9
270-360° left	0.0 \pm 0.0	2.3 \pm 3.6	0.6 \pm 1.9	1.0 \pm 2.5

Follow up Mann Whitney U tests: * significantly different to both other positions

The results in Tab. 8 demonstrated that player positions had a significant influence on the number of 0° to 90° left, 0° to 90° right and 270° to 360° left turns made in a match. The frequency per match of the remaining turns was not significantly different between the positions.

According results in study of (Bloomfield, et al., 2007), it could be said that soccer players are mostly changing their direction during the game with frequency of 0-90° grade in both right and left directions, and mostly moving in a forward direction, however a defender position moved mostly backward more than all other positions and this logically consisted with his requirements in the game. No significant difference observed in total movements in lateral and diagonal forward directions. However, the mean of diagonal forwards movements observed relatively more than lateral directions in both right and left sides. These results confirmed that, with agility conditioning programmes being undertaken by professional players, a full understanding of the agility requirements of soccer game is needed to inform the process of developing such programmes.

According to study of (Muniroglu, 2005) who stated that performance of acyclic speed and dribbling are affected by performance of cyclic speed run. In soccer, the importance of cyclic running has decelerated because of changes in the structure of play. Because action is limited to a narrow field, acyclic speed and dribbling can be more important in taking opponents out of play and gaining an advantage. It is suggested that speed drills should be formatted with both acyclic and different dribbling, which more directly supports the necessary qualities of modern soccer.

Therefore, some agility tests (Illinois Agility Run), correlate strongly with velocity whereas others correlate well with acceleration (505 test and T-test). This different relationship may affect the type of agility test chosen (Svensson & Drust, 2005). These different relationships influence the type of agility test chosen for inclusion in a test battery aimed at profiling performance of soccer

players. Therefore the test that is chosen should be one that adequately reflects the physical components of the individual's soccer performance to be tested.

The outcome of an agility test can also be used to discriminate elite soccer players from amateur players better than any other performance-based field test (Carling, et al., 2009). Soccer players at the elite level continually score in the excellent categories (according to agility test norms) for various agility tests whether the Illinois Agility Test or the Agility T-test. Evidence of this was demonstrated by the studies of (Little & Williams, 2005), who recorded scores for the Agility T-test of 6.87 ± 0.19 sec, (Eston & Reilly, 2009) and who reported scores for the Illinois Agility test of 16.54 ± 8.5 sec.

The coaches in soccer should also use agility tests in conjunction with single sprint tests to obtain a thorough indication of players speed capacity (Little & Williams, 2005). A good example of an agility test is that requires a player to perform two turns and several changes in direction (Balsom, 1994). Thus, according to studies of (Balsom, 1994; Bloomfield, et al., 2007), in this study will be used a zigzag run test called (FLT Z-Run sprint), that assess change of direction according to movements turning performance in soccer game.

The observations of these studies indicate that superior agility is therefore an important component of success in soccer at the elite level and agility tests are possibly one of the clearest indicators, as to the differentiation in standards between elite and amateur players or field team sports to describe the non-linear movement for each sport during match play.

2.2.2.2.3 Speed review in previous soccer studies

This part presents the previous published data in linear and non-linear sprint tests of elite and professional soccer players.

2.2.2.2.3.1 Linear sprint review studies in soccer

Distances of Linear sprint test in current study have categorized according study of (Kindermann & Meyer, 2001) as, the first 5 m of the linear sprints identified as reaction time and explosiveness sprint and is designed for soccer players of the highest importance, the 10 m provide information on the acceleration and 30 m identified as a basic maximum sprint for soccer player.

The literature reviewed in the following table includes studies published from the recent years to the present, which tested and reported linear sprint time scores over 5 m, 10 m and 30 m in elite and professional soccer players. This data was compiled with the linear sprint data that was collected in current study of professional soccer players in the Bundesliga to contribute the final soccer specific table of updated normative values.

According to previous studies in Tab. 9, the mean time sprint scores over 5 m, 10 m, and 30 m, which recorded by elite and professional soccer players from different nation leagues showed in range between 0.96 ± 0.04 to 1.46 ± 0.07 sec over 5 m, 1.66 ± 0.05 to 2.27 ± 0.04 sec over 10 m and 3.97 ± 0.12 to 4.28 ± 0.12 sec over 30 m.

Naturally, the mean values sprint profile difference between previous studies, may be caused by the methods of sprint testing procedures and the plan of time seasons in these countries. In any case, (Coen et al., 1998) have profiled the strong sprint performance for German national soccer players and identified that 5 m sprint time below 1 sec and the 30 m sprint time less than 4 sec.

Tab. 9: Comparison between linear sprint assessed in this study with reported values from previous studies for elite and professional soccer players (mean \pm SD)

References	Nationality	Level	n	5 m	10 m	30 m
				(sec)	(sec)	(sec)
(Meyer et al., 2000)	German	DFB elite (1991/1992)	34	0.96 \pm 0.04	1.66 \pm 0.07	3.98 \pm 0.09
(Meyer, et al., 2000)	German	DFB elite (1994)	25	0.98 \pm 0.04	1.68 \pm 0.04	4.0 \pm 0.09
(Meyer, et al., 2000)	German	DFB elite (1998)	35	0.97 \pm 0.04	1.66 \pm 0.05	3.97 \pm 0.12
(Tumilty, 2000)	Australian	Professional	37	1.03 \pm 0.05	1.74 \pm 0.04	---
(Cometti, et al., 2001)	France	Professional 1 st league	29	---	1.80 \pm 0.06	4.22 \pm 0.19
(Cometti, et al., 2001)	France	Professional 2 nd league	34	---	1.82 \pm 0.06	4.25 \pm 0.15
(Strudwick, et al., 2002)	English	Professional	19	---	1.75 \pm 0.08	4.28 \pm 0.12
(Wisloff, et al., 2004)	Norwegian	Elite	17	---	1.82 \pm 0.3	4.0 \pm 0.2
(Little & Williams, 2005)	English	Professional	106	---	1.83 \pm 0.08	---
(Muniroglu, 2005)	Turkish	Professional	177	---	---	4.14 \pm 0.17
(Dourado et al., 2007)	Brazilian	Professional	230	---	1.74 \pm 0.11	4.16 \pm 0.03
(Bisanz & Gerisch, 2008b)	German	Professional 1 st League	---	---	1.65	4.04
(Bisanz & Gerisch, 2008b)	German	Professional 2 nd League	---	---	1.69	4.10
(Taskin, 2008)	Turkish	Professional	243	---	---	4.26 \pm 0.13
(Reinhold, 2008)	German	Professional	---	1.04 \pm 0.03	1.75 \pm 0.04	4.13 \pm 0.12
(Sporis, et al., 2009)	Croatian	Elite	270	1.44 \pm 0.5	2.27 \pm 0.4	---
(Hoshikawa et al., 2009)	Japanese	Professional	30	0.99 \pm 0.02	1.72 \pm 0.04	---
(Boone et al., 2011)	Belgian	Professional	289	1.46 \pm 0.07	2.21 \pm 0.13	---
(Cotte & Chatard, 2011)	English	Professional Total	14	---	1.68 \pm 0.06	4.08 \pm 0.13
(Cotte & Chatard, 2011)	English	Professional International	---	---	1.70 \pm 0.10	4.12 \pm 0.14
(Cotte & Chatard, 2011)	English	Professional Non International	---	---	1.69 \pm 0.08	4.10 \pm 0.14
(Freiwald & Baumgart, 2012)	German	Professional	14	1.08 \pm 0.03	1.81 \pm 0.04	4.22 \pm 0.11
Present study	German	Professional	14	1.11 \pm 0.04	1.85 \pm 0.05	4.24 \pm 0.17

DFB = German soccer federation; --- = No available data; 1st = First; 2nd = Second

The level of leagues and competitions around countries must be taken in consideration because there is a relationship between sprint performance teams and their skill ability levels. For these reasons had (Geese, 1990) classified the sprint performance time levels for soccer players in the following table.

Tab. 10: Classification performance sprint time levels for soccer players (Geese, 1990)

Sprint time (sec)	Classification levels
< 3.95	Excellent
3.95 - 4.04	Good
4.05 - 4.14	Average
4.15 - 4.24	Poor
> 4.24	Very Poor

2.2.2.2.3.2 Non-Linear sprint review studies in soccer

In current study, the (FLT Z-Run sprint) test used to assess the ability of change of direction and turning for soccer players. Previous studies which used this test are limited. There are more studies in soccer have used change direction tests such as Illinois agility, Z-Run and zigzag run, which measured the non-linear sprint performance in soccer. The (FLT Z-Run sprint) test is similar to the Z-Run and zigzag tests, but the difference between them is the total distance of test, turning degrees, turning taking times and the tools that will be used to measure the total distance and turn times. The following table presents and combines the previous studies, which measured the ability of change direction movement in soccer players and the methods that used for these tests.

Tab. 11: Examples of (mean \pm SD) non-linear test results in previous studies for elite and professional soccer players

References	Test	Level	n	Time (sec)
(Power et al., 2005)	Illinois agility run	Professional	42	14.60 \pm 0.39
(Power, et al., 2005)	Illinois agility run	Professional	18	14.99 \pm 0.45
(Little & Williams, 2005)	Zigzag 20m run	Professional	106	5.34 \pm 0.20
(Little & Williams, 2006)	Zigzag 20m run	Professional	18	5.17 \pm 0.17
(Clark & Hons, 2007)	Illinois agility run	Professional (Suc)	70	16.29 \pm 0.45
(Clark & Hons, 2007)	Illinois agility run	Professional (Usuc)	70	16.35 \pm 0.48
(Taskin, 2008)	Four-line sprint	Professional	243	14.19 \pm 0.26
(Mirkov et al., 2008)	Zigzag 20m run	Professional	20	16.09
(Caldwell & Peters, 2009)	Illinois agility run	Semi professional	13	14.73 \pm 0.37
(Pieper, et al., 2010)	FLT Z-Run 22m	Professional RL 2008	11	5.70
(Pieper, et al., 2010)	FLT Z-Run 22m	Professional RL 2009	11	5.47
(Freiwald & Baumgart, 2012)	FLT Z-Run 22m	Professional BL	14	5.43 \pm 0.11
Present study	FLT Z-Run 22m	Professional	14	5.43 \pm 0.80

Suc = successful; Usuc = unsuccessful; RL = Regional league; BL = Bundesliga

According to previous studies in Tab. 11, which demonstrated mean values of non-linear sprint tests of professional soccer players. It could not be compared this data together because the difference between total distances of this tests are not similar. Based on the previous studies that used (FLT Z-Run sprint), soccer players in current study showed faster than regional league players (Pieper, et al., 2010), and had similar mean value to soccer players at the same league of (Freiwald & Baumgart, 2012). This difference may be caused due to several reasons such as training strategies, player's motivation and the time of fitness tests.

2.2.2.3 Speed characteristics of rugby players

Speed is an important requirement for playing the game in rugby union. It is important to gain an advantage over the opponents in all aspects of the game, e.g. chasing kicks, supporting line breaks and chasing down opponents. The aspect of speed that is most important in rugby is acceleration, as for the most part players run short distances. Sprint and agility training involves improving the ability to accelerate, improving a players top speed and also their ability to manage their body weight when changing direction (Welsh, WRU).

2.2.2.3.1 Linear sprint in rugby

In rugby union sport, the ability to accelerate quickly is important from either a stationary or a moving start and performs the fastest possible running speed. Particularly over short distances, is an important fitness component (Nicholas, 1997). Acceleration into the contact zone and running off a straight line have been identified as important characteristics of an effective ball-carrying performance (Sayers & Washington-King, 2005).

A study of (Duthie et al., 2006) found that rugby players regularly performed 90% of their maximum velocity speed in a rugby game and back-line players perform more sprints than forward players. Forward players generally require mostly speed component to accelerate away from line-out, scrum, ruck⁴ and

⁴ Ruck: A ruck is a phase of play where one or more players from each team, who are on their feet, in physical contact, close around the ball on the ground (www.irb.com).

maul⁵, while backline players need it to accelerate through tackles, thus outmaneuver their opponents and general running play (Duthie, et al., 2003).

(Duthie, et al., 2003) have compared rugby players results from recent studies in their study, and reported that rugby players should be tested in sprint for both acceleration and maximal velocity with intervals at 10 m (acceleration) and 30-40 m (maximal velocity split). In this comparable rugby study, the authors recorded that rugby players sprint over 30 m between 4.3 to 4.5 sec and over 40 m 4.81 to 6.26 sec.

The ability to accelerate and cover short distances becomes an important characteristic in rugby union which distinguishes the proficiency level of competitions and position role of players. In this context, Gabbett (2002b) reported 10 m and 40 m sprint time for players in different competition levels and player positions, first and second grade senior rugby back players recorded over 10 m 1.98 and 2.08 sec, forward players 2.05 and 2.14 sec, respectively. Sprint 40 m have back players recorded 5.69 and 5.81 sec, forward players 5.86 and 6.09 sec, respectively. Moreover, one study has established significant differences between forwards and backs 30 m sprint time and recorded means of 4.5 and 4.3 sec, respectively (Quarrie, et al., 1995).

The differences between forwards and backs will be primarily a result of the different roles in game, as backs have been shown to sprint longer than forwards (Deutsch, et al., 2007; Duthie, et al., 2003). Studies that have investigated the differences between levels players showed elite professional and first class players were significantly faster than sub-elite, second class and junior players over both the acceleration and maximal speed phases (Gabbett, 2002b; Quarrie, et al., 1995).

(Duthie, et al., 2006) examined the movement patterns of rugby players by video analysis during competition. Forwards perform 13 ± 6 sprints per game,

⁵ Maul: A maul occurs when a player carrying the ball is held by one or more opponents, and one or more of the ball carriers team mates bind on the ball carrier. A maul therefore consists of at least three players, all on their feet; the ball carrier and one player from each team. All the players involved must be caught in or bound to the maul and must be on their feet and moving towards a goal line (www.irb.com).

compared to be backs 24 ± 7 and the mean duration of sprints during a match for forwards was 2.5 ± 1.6 seconds compared to the 3.1 ± 1.6 seconds of backs. 87% of all the sprints during a match involved a change of direction. It has been recommended that during training and conditioning, players should accelerate from both standing and moving starts, reaching speeds in excess of 90% of the peak running speed.

(Deutsch, et al., 2007) quantified the movement patterns of various playing positions during professional rugby union match-play. This study reported mean sprint times ranging from 2.01 ± 0.77 sec for forwards and 3.84 ± 0.41 sec for backs. Based on fitness testing, have authors recommended that this times correspond to sprint distances of approximately 12 to 28m and for specific rugby union training it should be focused on distances of 10-15 m for forwards, 15-20 m for inside backs and 20-30 m for outside backs.

(Cunniffe et al., 2009) distinguished the match activity profiles of 2 elite rugby players, who competed in the Celtic league and Guinness Premiership. Player activities were coded into the following six categories, which presented in Tab. 12. The authors have consisted speed zones as follows: standing and walking ($0-6 \text{ km.h}^{-1}$), jogging ($6-12 \text{ km.h}^{-1}$), cruising ($12-14 \text{ km.h}^{-1}$), striding ($14-18 \text{ km.h}^{-1}$), high-intensity running ($18-20 \text{ km.h}^{-1}$) and sprinting ($>20 \text{ km.h}^{-1}$).

Tab. 12: Match activities in elite rugby players (Cunniffe, et al., 2009)

Categories	Activities intensity
Standing and walking	$0 - 6 \text{ km.h}^{-1}$
Jogging	$6 - 12 \text{ km.h}^{-1}$
Cruising	$12 - 14 \text{ km.h}^{-1}$
Striding	$14 - 18 \text{ km.h}^{-1}$
High-intensity running	$18 - 20 \text{ km.h}^{-1}$
Sprinting	$> 20 \text{ km.h}^{-1}$

In the following table, the authors have examined the differences of the match activities between playing positions, whose categories as back and forward. In this study, participated elite rugby players and were analyzed during the out-of season ($n=2$), using a Global Positioning System (GPS) software.

Tab. 13: Comparison covered distance of match performance activities between positions for elite rugby players* (Cunniffe, et al., 2009)

Categories match activities	n	Player positions	
		Back (m)	Forward (m)
Standing and walking	2	2802 (1247; 1314)	2409 (1124; 1110)
Jogging	2	1956 (794; 1054)	1856 (722; 948)
Cruising	2	673 (332; 330)	746 (310; 362)
Striding	2	978 (532; 439)	1011 (479; 481)
High-intensity running	2	292 (172; 120)	342 (138; 177)
Sprinting	2	524 (241; 283)	313 (157; 159)

*values inside parentheses are those for first and second halves, respectively

The results of study by (Cunniffe, et al., 2009) reported that, players covered on average 6953 m during the game. Of this distance, 37% (~2800m) was spent standing and walking, 27% (~1900m) jogging, 10% (~700m) cruising, 14% (~990m) striding, 5% (~320m) high-intensity running, and 6% (~420 m) sprinting. In comparison between back and forward players, back player covered more distance in jogging and sprinting than forward player. However, forward player covered more distance in high-intensity running than back player.

In addition, study of (Cunniffe, et al., 2009) suggested that, During the game players contained within 742 changes in tempo, occurring approximately every 3 to 4 sec. The back entered the high-speed zone ($>20 \text{ km.h}^{-1}$) on a greater number of occasions (34 vs. 19) than the forward. In turn, the forward entered the lower speed zone ($6\text{-}12 \text{ km.h}^{-1}$) on a greater number of occasions than the back (315 vs. 229) but spent less time standing and walking than the back (66.5 vs. 77.8%). Players reached maximum speeds of 28.7 km.h^{-1} (back) and 26.3 km.h^{-1} (forward), respectively.

In context of a rugby union game, have (Grant et al., 2003; Walsh et al., 2007) researched the effects of ball-carrying techniques on the speed for rugby players during the game. The results indicated that in sprinting with the ball under one arm was faster than with the ball in both hands. Study of (Grant, et al., 2003) examined two different linear sprint distances 10 m and 20 m. The mean \pm SD of 10 m sprint with carrying-ball under one arm and with ball in both hands were 1.87 ± 0.08 and 1.91 ± 0.10 sec, and 20m were 2.61 ± 0.12 and 2.65 ± 0.12 sec, respectively.

As same as results found in the results of (Walsh, et al., 2007) who's examined 20 m sprint with carrying-ball in two-hands, left-arm and right-arm, and the scores were 2.62 ± 0.16 , 2.61 ± 0.15 and 2.60 ± 0.17 sec, respectively. The studies suggest that players should incorporate some sprint training while carrying a rugby ball, as this could benefit the early phase of the sprinting run and increase running efficiency when on attack in a rugby game. In general, these factors make sprinting in rugby different from other sports. Despite these differences, elite rugby union coaches and conditioning staff still strive for their players to be able run quickly in a straight line (Duthie, et al., 2003).

According to studies of (Carling, et al., 2009; Cunniffe, et al., 2009; Deutsch, et al., 2007) who suggested, that 10-25 m is the most distance during match-play and recommended that testing for sprint ability usually takes the form of a 10 m, 20 m and 30 m. Therefore, in this study speed and acceleration over 30 m was measured as this is most relevant to the demands of the game.

2.2.2.3.2 Non-Linear sprint in rugby

Rugby union is a complex game that requires frequent short duration sprints with changes in multiple directions in reaction to other player movements during play (Deutsch, et al., 2007). Therefore, it must be suggested that rugby players need to adequate mobility and cutting performance, this sport need from players to react to game specific stimuli to effectively carry the ball or defend with opposite team.

In context rugby game, change direction movement patterns are expressed in a number of ways. A side-step and straighten non-linear running would be observed when an attacking ball carrier executes an initial side-step to outmaneuver an opponent and then straightens the running direction to advance the ball beyond the defensive line (Wheeler & Sayers, 2010).

(Duthie, et al., 2006) suggested that, rugby players during the game performed seventy-eight sprints (16%) involved a change of direction and were subsequently excluded from the estimation of velocity achieved. Forward

players had 2 ± 2 sprints (15%) per game that involved a change of direction, which was 4 ± 3 ($p = 0.03$) fewer than for the backs (6 ± 3 , 22%).

In review of literatures, several studies have investigated the ability to change direction and turning in rugby players. (Quarrie, et al., 1995) have used agility run test to distinguished between rugby player levels and positions in competition, which requires the player to turning around four cones. The results reported that, Senior A players were significantly better than Senior B players. In addition, back players were significantly better than forwards in both Senior A and B levels, 11.5 and 11.9 sec and 12.2 and 12.4 sec, respectively.

(Durandt et al., 2006) have used Illinois agility test to profiled elite junior South African rugby players. The test measured the player ability to accelerate, decelerate and change direction. Players sprinted 9 m, turned and returned to the starting line. After returning to the starting line they swerved in and out of four markers to completing two 9 m sprints to finish the agility course. No significant difference observed between U18 and U16 elite junior player, 15.1 ± 0.8 sec and 15.2 ± 0.9 sec, respectively. Also has (Gabbett, 2002b) used Illinois agility test to distinguished first and second grade rugby players. Forward and back Players in 1st grade showed significantly better than players in 2nd grade level, 17.2, 17.4 sec and 18.1, 17.7, respectively.

(Gabbett et al., 2008) have used three different changes of direction speed tests (505 test, Modified 505 test and L run test), whose have measured the ability non-linear sprint for 1st and 2nd rugby players. The mean (SD) values of 1st and 2nd players were, 505 test (2.34 ± 0.20 and 2.39 ± 0.15); Modified 505 test (2.66 ± 0.14 and 2.71 ± 0.17); L run test (6.36 ± 0.53 and 6.49 ± 0.40), respectively. However, no significant differences were observed between 1st and 2nd players for change of direction sprint in the three non-linear tests that used in this study.

In comparison with other sports, rugby players 8.0 ± 0.6 sec recorded slower times in agility test than soccer players, which require from players to perform an obstacle course in which jumping, rolling and bending movements as well as different changes of direction were demanded. This non-linear sprint test

compared with American footballers 7.8 ± 0.9 sec and soccer players 7.5 ± 0.7 sec (Kuhn, 2005).

(Walsh, et al., 2005) have cleared the importance of non-linear sprints in rugby union and soccer players. They suggested that, one reason for the occurrence of non-linear sprints in rugby and soccer is that in both rugby and soccer there are opponents from the other team that have to be avoided on the way towards the goal. In this study, rugby and soccer players have completed a zigzag course test, which require of players to sprint 24.5 m. Correlation analysis was performed to determine reliability of the individual non-linear zigzag sprint test, rugby and soccer players performed the correlations between the test and retests $r = 0.662$ ($p, 0.006$) and $r = 0.855$ ($p < 0.000$), respectively.

The correlation analysis in study of (Walsh, et al., 2005) confirmed the test objectivity of (Bös, et al., 2000) for a non-linear test as a tool to distinguished between soccer and rugby players, who identified that middle correlation located between $0.40 \leq 0.69$ and the high correlation is $0.70 \leq 0.99$. Thus, the (FLT Z-Run sprint) test in current study will demonstrating the difference between rugby and soccer players, as a test measure the ability to change direction in field team sports.

In any case, measurements of agility to investigate non-linear sprint ability are difficult to compare across recent studies due to the different test protocols. In addition, there are limitation of studies such as study of (Bloomfield, et al., 2007) for elite soccer players, who examined the multidirectional movements for soccer players during the game. Therefore, the time motion analysis studies for rugby players should be take that in considered.

2.2.2.3.3 Speed review in previous rugby studies

This part presents the previous published data in linear and non-linear sprint tests of elite and professional rugby players.

2.2.2.3.3.1 Linear sprint review studies in rugby

Distances of Linear sprint test over 5 m, 10 m and 30 m in current study have categorized according (Taplin, 2005), who identified these distances when a rugby players need to assess for a linear sprint performance. Scientific data for rugby players are relatively limited. Therefore, the following table presents linear sprint data, which measured linear sprint in elite and professional male rugby players.

Tab. 14: Comparison between linear sprints assessed in this study with reported values from previous studies in elite and professional rugby players (mean \pm SD)

References	Nationality	Level	n	5 m	10 m	30 m
				(sec)	(sec)	(sec)
(Quarrie, et al., 1995)	New Zealander	Senior A (F)	45	---	---	4.50
(Quarrie, et al., 1995)	New Zealander	Senior A (B)	37	---	---	4.30
(Quarrie, et al., 1995)	New Zealander	Senior B (F)	12	---	---	4.80
(Quarrie, et al., 1995)	New Zealander	Senior B (B)	12	---	---	4.50
(Jenkins & Reaburn, 2000)	Australian	Professional	14	---	1.80 \pm 0.80	---
(Gabbett, 2002a)	Australian	Professional 1 st Grade	31	---	2.15 \pm 0.15	4.81 \pm 0.16
(Gabbett, 2002a)	Australian	Professional 2 nd Grade	35	---	2.19 \pm 0.11	4.80 \pm 0.17
(Walsh, et al., 2007)	American	Professional Players	22	---	1.87 \pm 0.10	---
(Gabbett, et al., 2008)	Australian	Professional 1 st Grade	12	1.14 \pm 0.06	1.90 \pm 0.09	---
(Gabbett, et al., 2008)	Australian	Professional 2 nd Grade	30	1.20 \pm 0.11	2.00 \pm 0.14	---
(Crewther, et al., 2011)	English	Professional	30	---	1.69 \pm 0.10	---
(Green et al., 2011)	Ireland	Professional Club	11	---	2.04 \pm 0.16	4.58 \pm 0.33
(Green, et al., 2011)	Ireland	Professional Academy	17	---	1.70 \pm 0.05	4.17 \pm 0.14
Present study	German	Elite	14	1.11 \pm 0.04	1.85 \pm 0.05	4.24 \pm 0.17

(F) = Forwards; (B) = Backs; --- = No available data

According to previous studies in Tab. 14, the mean time sprint scores over 5 m, 10 m, and 30 m, which recorded by elite and professional rugby players from different nation leagues showed in range between 1.69 ± 0.10 to 2.19 ± 0.11 sec over 5 m, 4.17 ± 0.14 to 4.81 ± 0.16 sec over 10 m and 4.17 ± 0.14 to 4.81 ± 0.16 sec over 30 m. In any case, the level of leagues, competitions and sprint testing procedures must be taken in consideration. Based on the best time score that recorded for professional rugby players in literature, (Luger & Pook, 2004) have classified the linear sprint performance levels over 10 m and 30 m distances for professional rugby players in the following table:

Tab. 15: Classification performance sprint time levels over 10 m and 30 m for professional rugby players

Linear Sprint Test	Average (sec)	Good (sec)	Excellent (sec)
Sprint 10 m	2.10 to 2.25	2.00 to 2.10	< 2.00
Sprint 30 m	4.25 to 4.45	4.00 to 4.25	< 4.00

According to the rank of sprint times in Tab. 15, it could be said that rugby players sprint time score over 10 m and 30 m showed excellent and average level, respectively.

2.2.2.3.3.2 Non-linear sprint review studies in rugby

There are no previous studies, which reported mean values of (FLT Z-Run sprint) for rugby players. The following table will presents the data of previous studies that used non-linear sprint tests for rugby players.

Tab. 16: Examples of (mean \pm SD) non-linear test results in previous studies for elite and professional rugby players

References	Test	Level	n	Time (sec)
(Quarrie, et al., 1995)	Agility run	Senior A	92	11.85
(Quarrie, et al., 1995)	Agility run	Senior B	37	12.15
(Gabbett, 2002a)	Illinois agility	1 st Grade	31	16.9 ± 0.9
(Gabbett, 2002a)	Illinois agility	2 nd Grade	35	17.4 ± 1.3
(Baker & Newton, 2008)	A Novel test	Prof	20	8.89 ± 0.37
(Baker & Newton, 2008)	A Novel test	Semi Prof	20	8.94 ± 0.24
(Gabbett, et al., 2008)	505 test	1 st Grade	12	2.34 ± 0.20
(Gabbett, et al., 2008)	505 test	2 nd Grade	30	2.39 ± 0.15
(Gabbett, et al., 2008)	Modified 505 test	1 st Grade	12	2.66 ± 0.14
(Gabbett, et al., 2008)	Modified 505 test	2 nd Grade	30	2.71 ± 0.17
(Gabbett, et al., 2008)	L run	1 st Grade	12	6.36 ± 0.53
(Gabbett, et al., 2008)	L run	2 nd Grade	30	6.49 ± 0.40
Present study	FLT Z-Run 22m	Prof	14	5.86 ± 0.18

1st = First; 2nd = Second and Prof = Professional

Previous studies in Tab. 16 demonstrated mean values of non-linear sprint tests of elite and professional rugby players. Measurements of sprint non-linear test are difficult to compare across previous studies due to the different test protocols and the timing of the tests or the training stimulus. In overview of results in above table, rugby players in second league observed slower than first leagues players across previous studies.

These results suggest that player skills and performance level of competitions could be reflected this differences between players. There is no available data of (FLT Z-Run sprint) for rugby players. Therefore, it may be that (FLT Z-Run Sprint) test will be useful to examine the ability of changing direction of rugby players and for sub-elite players, when tested for talent identification or developing their training.

2.2.3 Strength

The requirement for a particular strength quality for a team sports player will depend on the typical demands placed upon them during competition and also the natural of these sports (Gamble, 2010). Muscular strength is generally acknowledged as being important factor in sports that are dominated by speed such as soccer and rugby union, which relates with a large endurance component. Given the importance of muscular strength in so many sports, the coach and player must understand how the development of strength can affect sport performance and need to understand the principles associated with resistance training to effectively use resistance training to enhance performance (Bompa & Haff, 2009).

2.2.3.1 Definition and structure of strength

The term strength will be employed to identify the maximal force or torque that can be developed by the muscles performing a particular joint movement (e.g. elbow flexion, knee extension). However, the muscles may perform at maximal effort as either isometric, concentric or eccentric actions and the two dynamic actions may be performed at a wide range of velocities (Komi, 2003).

Therefore, strength is not the result of a measurement performed under a single set of conditions because of the number of variables or conditions involved strength of a muscle or muscle group, strength must be defined as the maximal force a muscle or muscle group that can generate at a specified or determined velocity. Also strength is the ability to develop force against an unyielding resistance in a single contraction of unlimited duration (Maud & Foster, 2006).

Strength is the maximal force produced by a muscle or muscles at a given speed. Power is the product of force (strength) and velocity (speed) (Hamill & Knutzen, 2009). The parameter that describes a force being applied over a given distance (work performed) in a given time is power. For the purpose of this, power will be defined as force x distance/time (also work/time) and maximal power (P_{max}) will be defined as the highest average power output during the concentric phase of a muscular contraction (Baker, 2001).

Some definitions of strength are as follows, (Baechle & Earle, 2008) has defined strength as “Strength is the maximal force that a muscle or muscle group can generate at a specified velocity” and (Bompa & Haff, 2009) as a maximal force or torque (rotational force) a muscle or muscle group that can be generated.

(Dick, 2007; Weineck, 2004) divided strength into four types:

- Maximal strength
- Speed strength
- Reactive strength
- Endurance strength

Maximal strength is the highest level of force that can possibly generated of a player. Its importance will vary between sports but this relates more to the length of the maximal strength training phase than whether it should be included or not. The greater a players maximal strength to begin with, the more of it can be converted into sport-specific strength endurance or explosive power (Bompa & Haff, 2009). As same as has (Dick, 2007) defined maximum strength as the greatest force that the neuromuscular system is capable of applying in a single maximum voluntary contraction.

Speed strength ability defined by (Weineck, 2004) as a component of the explosive power and results from the slope values of a force-time curve. From the three components maximum power, speed and explosive force, the speed strength ability will be formed in muscle contractions. (Martin, 1999) refers that speed strength, is the ability to quickly make optimal force. The rapid force is composed as a complex property of the component strength and speed.

Reactive strength concerns the coupling of eccentric and concentric muscle actions, and as such comprises both eccentric and concentric speed strength qualities, also in addition to stretch shorting cycle components (Gamble, 2010). Reactive strength defined by (Bompa & Haff, 2009) as the ability to change quickly from an eccentric to a concentric contraction.

Endurance strength is dependent on the components of strength and endurance and can be defined as the maximum force dependent on the fatigue resistance to extended repetitive stress under static or dynamic muscle work (Dick, 2007). The application of endurance strength is the ability to counter the fatigue produced by the strength load components of an activity over a prolonged period of time (Bompa & Haff, 2009).

Maximum strength is the principle component for field team sports such soccer and rugby union. Player's body weight and the performance activities in game are closely correlated together. (Dick, 2007) demonstrated the difference between absolute and relative strength and suggested that, heavy players can in absolute terms achieve greater strength expression than lighter players. The maximum force that player can express, regardless of body weight, is therefore referred to as absolute strength. On other hand, the maximum force that player can express in relation to body weight is known as relative strength.

(Hoff, 2005) stated that strength testing should take place for the upper and lower body and should be evaluated using a 1 RM test of half squat and bench press. This gives an indication of the greatest amount of weight an individual can lift for each exercise, and also provides information on the athletes training loads calculated as a percentage of the 1 RM.

Therefore, the understanding of strength importance for field team players such as soccer and rugby union could give coaches overview about strength training intensity. Thus, the next part demonstrates the benefits of strength as an important factor for soccer and rugby union.

2.2.3.2 Strength characteristics of soccer players

2.2.3.2.1 Benefits of strength in soccer

Muscular strength takes many forms in soccer. Players need the muscular strength in various activities during soccer matches such as starts, stops, sprint, jumps, dribbling, kick the ball, head ball and tackling. In particular, the muscles strength of the trunk is necessary because it is required during the tackling with the ball (Bisanz & Gerisch, 2008b).

Soccer is a strength related sport and therefore requires both absolute strength (e.g. for kicking and body contact with opponents) and relative strength (e.g. running and jumping). Thus it would appear that muscular strength is a very important component of physical performance in soccer, in terms of both high-level performance and injury occurrence (Stolen, et al., 2005). Moreover, power is heavily dependent on maximal strength, with an increase in the latter being connected with an improvement in power capabilities (Wisloff, et al., 2004).

(Reilly & Williams, 2003) stated that the benefits of strength training in soccer players were three aspects:

- to increase muscle power output during explosive activities such as tackling, jumping, kicking and accelerating,
- to prevent injuries, and
- to regain strength post injury.

(Wisloff, et al., 2004) indicated that increasing strength in soccer players increases parameters of power such as jumps and sprints. They found a strong correlation between squat strength, jumping height and all aspects of 30m sprint performance in elite soccer players. The results showed that, the level of 1RM correlated well with the 10m sprint time ($r = 0.94, p < 0.001$), 30m sprint time ($r = 0.71, p < 0.01$) and jumping height ($r = 0.78, p < 0.02$). In addition, vertical jump

height performance correlated with both 10m ($r = 0.72$, $p < 0.001$) and 30m sprint time ($r = 0.60$, $p < 0.01$). Thus, it is beneficial for a soccer player to have a high level of muscular strength.

The results of (Wisloff, et al., 2004) consisted with (Bangsbo, 1994c) who suggested that the acceleration and speed in skills critical to soccer such as turning, sprinting and changing pace will be improved by increasing the available force of muscular contraction in appropriate muscles or muscle groups.

(Reilly, 1996) stated that upper body strength is employed during throwing and it is proved that upper body strength helped in preventing being knocked off the ball. In addition, lower body muscular strength important fitness elements for speed, jump, kick, tackle and turning.

(Bangsbo, 2003) suggested that the explosive strength of the leg muscles is related to speed in soccer game, when player needs to be able to quickly change direction. This may be explained why soccer players seem to have comparative advantages when they came to contact on the field.

Thus, high levels of maximal strength in upper and lower body are important for soccer players. This is in accordance with previous studies and emphasizes that muscular force and power and thus vertical jumping ability is a crucial part of game play and thus vital to a player's successful performance especially for defensive players (Reilly & Williams, 2003; Stolen, et al., 2005).

However, tests that involve free barbells will reflect the functional strength of players more accurately (Hoff & Helgerud, 2004). Also, free barbells are more widely accessible for teams for both training and testing purposes. (Hoff, 2005) stated that strength testing should take place for the upper and lower body and should be evaluated using a 1 RM test of half squat and bench press.

Therefore, the measurement of maximum muscular strength is most commonly assessed using the weight that can be lifted once such as 1RM in the bench press (for the upper body) and the back squat (for the lower body). The next part will demonstrate the previous studies that investigated maximum strength for soccer players, as an important factor for coaches and players.

2.2.3.2.2 Strength review in previous soccer studies

The following table includes previous studies from the recent years to the present, which assessed and reported mean value of one repetition maximum strength test for upper and lower body in elite and professional soccer players. These data were compiled with the 1RM bench press and back squat data that collected in this study of elite and professional soccer players to contribute a final soccer specific table of updated normative values.

Tab. 17: Comparison between assessed upper and lower strength tests in this study with reported values from previous studies in elite and professional soccer players (mean \pm SD)

References	Nationality	Level	n	Bench press	Back squat
				(kg)	(kg)
(Wisloff, et al., 1998)	Norwegian	Elite	29	79.9 \pm 13.6	150 \pm 17.2
(Wisloff, et al., 2004)	Norwegian	Elite	17	---	171.7 \pm 21.2
(Brick & O'Donoghue, 2005)	Ireland	Professional	22	80 \pm 11.7	---
(McIntyre, 2005)	Ireland	Professional		68.1 \pm 13	---
(Wong et al., 2010)	Hong Kong	Professional	39	65.3 \pm 1.5	123 \pm 1.5
(Bogdanis et al., 2011)	Greeks	Professional	10	---	142 \pm 3
(Bogdanis, et al., 2011)	Greeks	Professional	10	---	152 \pm 4
(Rønnestad et al., 2011)	Norwegian	Professional	19	---	139 \pm 7
(Jandacka & Uchytíl, 2011)	Czech Republic	Professional	15	83.3 \pm 11.2	---
(Freiwald & Baumgart, 2012)	German	Professional	14	85.38 \pm 9.89	---
Present study	German	Elite	14	87.86 \pm 12.20	257.86 \pm 35.99

According to previous studies in Tab. 17, the mean range in (1RMbp) of elite and professional soccer players in different leagues was 65.3 \pm 1.5 to 85.38 \pm 9.89 kg. In addition, the (1RMbs) reported range mean between 123 \pm 1.5 to 171.7 \pm 21.2 kg. The following table presents the mean values of (1RMbp) and (1RMbs) tests of study by (Wisloff, et al., 1998) who examined the (1RMbp) and (1RMbs) tests in Twenty-nine elite soccer player according to their positions, whose categorized as defenders, midfielders and attackers.

Tab. 18: Comparison 1RM bench press and back squat between positions in elite soccer players (mean \pm SD) (Wisloff, et al., 1998)

Player positions	n	1RM Bench press (kg)	1RM Back squat (kg)
Defenders	13	83.5 \pm 18.1	153.6 \pm 27.7
Midfielders	7	74.6 \pm 16.5	130.8 \pm 18.6
Attackers	9	79.8 \pm 10.7	147.5 \pm 23.8

The authors found no significant differences in (1RMbp) and (1RMbs) between the three different playing positions. However, defenders and attackers player strength means observed relatively better than midfielders player. These findings may be explained by the tendency for defense and attack players to be involved in more jumping and tackling compared with midfield players.

2.2.3.3 Strength characteristics of rugby players

2.2.3.3.1 Benefits of strength in rugby

Muscle strength is clearly employed in a host of activities during rugby union match play, especially because of the contact nature of the sport (Reilly, 1997). Strength and power are important necessary physical qualities for successful participation in rugby sport. As is not only necessary to be strong to effectively tackle, push or pull opponents or resisting high level of forces during scrums, rucks and mauls but also to generate these high levels of strength with speed (Meir et al., 2001).

(Baker & Newton, 2008) suggested that increase leg strength and power would act favorably for players in all components of the rugby. Increased leg strength and enabling increased leg drive would support tackling opposing players, when defense opposing other team players and in helping to break tackles when players in attacking situation.

In context of rugby union game and the different roles that the players need to use strength. (Duthie, et al., 2003; Nicholas, 1997; Reilly, 1997) suggested that the muscle strength is required for forwards in all aspects of scrummaging where force is applied isometrically in the first instance and coordinated in a team push. It is also required in rucks, mauls, ripping the ball from opponents and by all players in tackling and breaking tackles.

(Bompa & Claro, 2009) stated that strength and power are the most important qualities for any rugby player for two fundamental reasons:

- Specific positions in rugby require strong and powerful players.
- Speed, agility, and quickness are strongly dependent on strength and power.

In comparison between playing positions, (Maud, 1983) used one repetition maximum bench press and leg press tests to assess the dynamic muscular strength of USA amateur rugby players. The results demonstrated that the mean data of forwards recorded higher absolute mean values (mean bench press $90.4 \pm 9.8\text{kg}$) compared to the backs ($79.9 \pm 8.6\text{kg}$). This differential was reversed in the one repetition maximum leg press, with the backs (mean leg press $288.1 \pm 38.1\text{kg}$) outperforming the group of forwards (mean leg press $269.3 \pm 25.2\text{kg}$).

These strength ability observations for upper and lower body in rugby players consistent with those of (Crewther, et al., 2011) who stated that the larger body mass may be reflected the muscular adaptation, which occurs as a function of the strength requirements to enable them to withstand and transmit the forces applied whilst scrumming. In context of rugby player positions (Quarrie, et al., 1996) have suggested that the forwards are generally stronger than backs in both upper and lower body strength due to requirements of strength in scrums and the higher frequency in which the forwards are involved in tackles and ruck situations.

In comparison to other football codes, The muscular strength of rugby players as measured by the maximum bench press recorded mean of 86 kg that was higher than soccer players, slightly better but not significantly different from Australian Rules players 82 kg but considerably lower to the average mean of 138 kg achieved by American footballers (Reilly, 1997). These observations in maximum bench press were consistent with those of (Brick & O'Donoghue, 2005) who profiled the fitness characteristics for football codes sports, the results showed that the mean \pm (SD) rugby player forwards $109.7 \pm 26.7\text{ kg}$ and

backs 88.6 ± 7 kg were higher than average mean of soccer players 80 ± 11.7 kg.

A common test for strength within literature is the use of 1RM specifically squats and bench press exercises to assess lower and upper body strength. Upper body strength of professional players appear to be comparable between sports, with 1RM bench press 140 kg similar in both rugby union and rugby league players (Argus, et al., 2009; Baker, 2002; Crewther, et al., 2011). Additionally, has (Baker, 2002) stated that strength increases when rugby playing level increases. For example, significant differences in 1RM bench press have been reported between professional 144 kg, college 111 kg, high school 98 kg and junior 85 kg. Further work is therefore required to compliment these findings and to establish trends and differences in relative strength within higher level players.

According to above studies, it appears that rugby players require a high degree of muscularity combined with exceptional levels of upper and lower body strength. The evaluation of strength could assist in the development of scientific knowledge in rugby union. Therefore, in current study will be presented the mean values data of bench press and back squat tests that reported from previous studies. Theses data would be useful for coaches to control their strength training and clear the improving strength over past years for professional rugby players.

2.2.3.3.2 Strength review in previous rugby studies

The following table includes previous studies from the recent years to the present, which assessed (1RMbp) and (1RMbs) strength tests in elite and professional rugby players. These data were compiled with the strength data that collected in current study from rugby players in international German team to contribute a final rugby specific table of updated normative values.

Tab. 19: Comparison between assessed upper and lower strength in this study with reported values from previous studies in elite and professional rugby players (mean \pm SD)

References	Nationality	Level	n	Bench press	Back squat
				(kg)	(kg)
(Nicholas & Baker, 1995)	British	Prof	30	107.25	---
(Meir, et al., 2001)	British-Australia	Prof	118	118.5	---
(Brick & O'Donoghue, 2005)	Ireland	Prof	14	99.15	---
(Baker & Newton, 2008)	Australian	Elite	20	---	175 \pm 27.3
(Baker & Newton, 2008)	Australian	Prof	20	---	149.6 \pm 14.3
(Argus, et al., 2009)	New Zealand	Prof	32	141	194
(Argus, et al., 2011)	New Zealand	Prof	18	---	147.9 \pm 26.8
(Appleby, et al., 2011)	Australian	Prof (2007)	20	132.5 \pm 14	164.6 \pm 31.5
(Appleby, et al., 2011)	Australian	Prof (2008)	20	141.6 \pm 12.6	178.6 \pm 26.1
(Appleby, et al., 2011)	Australian	Prof (2009)	20	146.8 \pm 11.5	179.1 \pm 26.7
(Crewther, et al., 2011)	New Zealand	Elite	30	140 \pm 16.3	159.5 \pm 26.3
(Welsh, WRU)	Wales	Prof	---	138	189.63
Present study	German	Elite	14	100.71 \pm 15.30	209.29 \pm 44.28

Prof = Professional and --- = No available data

According to previous studies in Tab. 19, the mean range in (1RMbp) of elite and professional rugby players in different leagues was 99.15 to 146.8 kg. In addition, the (1RMbs) reported range mean between 147.9 to 194 kg. The difference mean values between rugby players from different countries in above table may be due to several factors such as test times, the number of repetitions in training sessions and strength training plan of rugby coaches in these countries.

(Welsh, WRU) manual fitness suggested that range mean of professional rugby players in (1RMbp) was 127 to 155 kg and (1RMbs) from 171 to 223 kg. This finding consisted with current study that profiled German rugby players at low level in (1RMbp) than other countries and confirmed that the mean of (1RMbs) test showed in range mean value for professional rugby players. In addition,

(Taplin, 2005) has classified the performance strength levels in (1RMbp) and (1RMbs) strength tests for amateurs rugby players in the following table:

Tab. 20: Classification one repetition maximum tests of bench press and back squat in amateurs British rugby players (Taplin, 2005)

1RM strength Test	Excellent (kg)	Good (kg)	Average (kg)	Poor (kg)
Bench press	115	105	95	85
Back squat	140	130	120	110

According to the ranking strength upper and lower ability in above table, it could be said that German rugby players in (1RMbp) and (1RMbs) strength tests showed at average and excellent level to British amateur players, respectively. In current study, (1RMbp) and (1RMbs) strength tests have been used to assess the upper and lower strength for rugby players. These tests should be conducted in an appropriate weight training areas with well maintained equipment. Therefore, discussions section will be compare the difference between rugby players from different countries and clear, how could these data used for sub elite identifications and control strength training.

2.2.4 Endurance

Endurance as a high level of aerobic fitness characteristics in field team sports helps to maintain the work rates related with team play, supporting team matches, running off the ball and chasing opponent players from other team to get back possession (Carling, et al., 2009).

Physical fitness characteristics in field team sports as strength and power, which related strongly to game activities that involves acceleration, sprinting and jumping share importance with endurance in explaining differences in physical fitness characteristics within soccer and rugby players performance. Therefore, the understanding of aerobic endurance as an important factor in field team sport matches will be demonstrates in this study. In this section in thesis, it will be presented the important aerobic endurance factors study as VO_{2max} and match covered distance in soccer and rugby players.

2.2.4.1 Definition and structure of endurance

In general, aerobic endurance is the amount of oxygen intake during exercise. This definition isn't enough to define aerobic endurance exactly. (Bompa & Haff, 2009) suggested that endurance could be classified as several ways such as aerobic endurance, low intensity exercise endurance or define as the ability that allow a player to perform activities continually for a long duration.

Endurance is directly or indirectly of high importance in all sports. It is however not easy to define endurance, but there is agreement regarding the following aspects endurance: it related to doing work for a long time of period, it relates to working under fatigue conditions, it involves a large number of muscles and it involves work efficiency. (Heyward, 2006) defines endurance as "the ability of the heart, lungs, and circulatory system to supply oxygen and nutrients to working muscles efficiently".

(Schnabel, et al., 2003; Thiess & Schnabel, 1995) also defines endurance as the resistance ability to fatigue, (Shephard & Astrand, 2000) have also used to the concept of ability to resist fatigue for defining endurance as "the ability to do sports movements, with the desired quality and speed, under conditions of fatigue". In context of field sports has (Mahler, 1995) defined endurance as the ability to perform dynamic exercises that involving large muscle groups at moderate to high intensity for extended periods.

2.2.4.2 Endurance characteristics of soccer players

Soccer is a team sport that depends on aerobic endurance and short term, high intensity intermittent activities (Bangsbo, 1994a; Hoff & Helgerud, 2004; Mohr, et al., 2003). According to soccer game demands, (Hoppe, et al., 2012) suggested that, soccer players need a well-developed ability to perform repeated short high intensity running activities over two 45-minute periods, which can be seen as intermittent endurance capacity. Thus, the important aerobic endurance factors;

- Covered distance, and
- Maximal oxygen uptake (VO_{2max}),

which related to soccer game will provide coaches soccer team with useful information that will assist in improving performance.

2.2.4.2.1 Covered distance of soccer players

The physical demands of outfield players have been widely reported using several different techniques, which include video analysis, hand notation and trigonometry (Bangsbo, Mohr, & Krustup, 2006). Time motion analysis of soccer match play has developed due to the fact that many spectators, coaches and players are avidly involved in the game (Ekblom, 1994). Therefore, utilizing time motion analysis of matches has allowed detailed and objective recordings of match events performance.

(Reilly, 1990) suggested that top division players covered a total mean distance of 8.6 km. The physiological demands of the game have increased over the last twenty years, and this improving could be observed of the total covered distance in professional soccer game (Bangsbo, 1994c; Jansen et al., 2010; Tumilty, 1993).

According to the comparable soccer players results of (Stolen, et al., 2005), soccer players during matches cover a total running distance of about 7 to 13 km with repeated short high-intensity running activities. This suggests that the average soccer player's physical condition has improved over the last years. Several reasons exist for such changes in distances covered, such as changes in tactics and playing styles.

The distance covered during a game has also been related to the level of competitive play, the higher distances being covered in the top leagues (Reilly et al., 2008). It has also been suggested that, because of greater levels of competition, there has been a move towards a faster pace of play and therefore an increase in the distance covered over the course of a game (Shephard, 1999).

The increases cover distance in soccer game may be due to several new rules introduced during recent years. In 1992 the rule against goalkeepers handling a pass from a team mate was introduced. Five years later goalkeepers were

instructed that they only had a limited time 6 sec to keep the ball in their hands before it had to be returned to open play. More recently the extra balls situated around the soccer field have been introduced in an attempt to increase effective playing time. Such changes to the laws will mean that top high level soccer players are required to perform more multiple sprints and higher intensity runs and to recover from them more quickly (Dupont et al., 2004).

There are large numbers of previous studies, which have been investigated the total covered distance for soccer players during a game. The following table demonstrates previous studies during recent years that recorded the total covered kilometers of elite and professional soccer players.

Tab. 21: Comparison total covered distances by elite and professional soccer players during soccer game according to (Stolen, et al., 2005; Tschan et al., 2001).

References	Year	Nationality	Level	Covered Distance (m)
Reilly et al.	1976	British	Professional	7.100-10.900
Withers et al.	1982	Australian	Professional	11.500
Winkler	1983	German	Professional	9.790
Winkler	1985	German	Professional	9.000-12.000
Eklblom	1986	Sweden	Professional	9.600-10.600
Ohashi et al.	1988	Japanese	Professional	9.300-10.400
Bangsbo et al.	1991	Denmark	Professional	10.100-11.400
Bangsbo et al.	1992	Sweden	Professional	8.990-10.200
Bangsbo	1994	Denmark	Professional	9.400-10.800
Müller et al.	1996	Austrian	Professional	8.923
Rienzi et al.	2000	British	Professional	10.104
Strudwick et al.	2001	British	Professional	11.300
Moher et al.	2003	Denmark	Professional	10.300
Moher et al.	2003	Italian	Professional	10.900
Bangsbo et al.	2006	Denmark	Elite	10.000-13.000
Di Salvo et al.	2007	Spanish	Professional	11.393
Moher et al.	2008	Denmark	Elite	10.330-10.440
Bradley et al.	2009	British	Professional	10.714
Andrzejewski	2012	UEFA Cup	Professional	11.288

Previous studies in above table reported mean range of total covered distance between 7-13 km in elite and professional soccer players during matches. The difference between soccer players from different countries may be related to several reasons such as tactics employed, styles and systems of play, the nature of the game and opposition and the physical capacity of the players can all influence distances covered.

Study by (Mohr, et al., 2003) found that within each playing position there was a significant variation in the physical demands depending on the tactical role and the physical capacity of the players. The authors observed that during the same match one midfield player covered 12.3 km with 3.5 km at speeds greater than 15 km.h⁻¹ while another midfielder covered only 10.8 km with 2.0 km at speeds greater than 15 km.h⁻¹.

(Di Salvo et al., 2007) have been examined the differences of the match covered distance between playing position, whose categories as central defenders, external defenders, central midfielders, external midfielders and forwards Tab. 22. In this study, participated Twenty Spanish Premier League matches and ten Champions League games were monitored in the 2002/2003 and 2003/2004 seasons (n=300), using a multiple camera match analyses system.

Tab. 22: Comparison covered distances in soccer match between player positions in elite soccer players (mean \pm SD) (Di Salvo, et al., 2007)

Player positions	n	Mean distance covered (m)
Central defenders (CD)	63	10.627 \pm 893 ^b
External defenders (ED)	60	11.410 \pm 708 ^c
Central midfielders (CM)	67	12.027 \pm 625 ^a
External midfielders (EM)	58	11.990 \pm 776 ^a
Forwards (F)	52	11.254 \pm 894 ^c
Total of team	300	11.393 \pm 1.016

^a Significantly greater distance covered than CD, ED, F; ^b significantly smaller distance covered than any other subgroup; ^c significant different from CD, CM, EM. Significant difference at ($p < 0.05$)

The results of (Di Salvo, et al., 2007) showed that, mean \pm (SD) total of distance covered over the period of the whole match by all players 11.393 \pm 1.016 m, ranging from 5.696 to 1.3746 m. The results in Tab. 22 demonstrated that CM and EM players covered a significantly greater distance ($p < 0.05$) than both defender groups, as well as the group of forwards. The distance covered by the CD, however, was significantly shorter ($p < 0.05$) than that of any other group, whereas ED did not differ from forwards.

As same as, (Andrzejewski et al., 2012) have been examined the differences of the match covered distance between playing position, whose categories as defenders, midfielders and forwards. In this study participated, thirty-one players

in four European Football Association (UEFA) Cup matches from the 2008 to 2009 season, using computerized match analysis system. The authors reported mean \pm (SD) total of distance covered over the period of the whole match by all players 11.288 ± 734 m, with only 105 m difference of the total mean value that reported by (Di Salvo, et al., 2007).

According to the player positions on the field, (Andrzejewski, et al., 2012) reported that the longest distance was covered by the midfielders at (11.770 ± 554 m) and recorded 3% longer than the distance achieved by the forwards (11.377 ± 584 m) and 7% longer than the defenders (10.932 ± 728 m). The results revealed a statistically significant difference only between the midfielders and the defenders.

According to research concerning positional demands in soccer, the results of (Andrzejewski, et al., 2012; Di Salvo, et al., 2007) consisted with (Reilly & Gilbourne, 2003; Strudwick, et al., 2002) whose indicated that the midfield players and full backs cover significantly greater distances than central defensive players, whereas (Reilly, 1990) stated that the role demands of a goalkeeper are more anaerobic and are reflected in substantially lower distance covered (4 km) during the game.

The increased distance covered by midfield players may reflect more moderate intensity activity sustained over longer periods during the soccer match, which may indicate that midfield players require a more aerobic endurance activity profile when compared to defender and attacker player positions. It is also possible that more tactical limitations may be placed upon them than other playing positions, due to the area in which midfielders tend to play.

Therefore, (Bangsbo, 2003) has identified the aims of aerobic endurance training for soccer players to:

- increase the capacity of the oxygen transporting system,
- increase the capacity of muscles to utilize oxygen during prolonged periods of exercise, and

- increase the ability to recover rapidly after a period of high-intensity exercise.

Thus, performance in endurance events is then heavily dependant on the adequate delivery of oxygen from the atmosphere to cytochrome oxidase in the mitochondrial electron transport chain, and the supply of fuels in the form of carbohydrates and lipids.

2.2.4.2.2 Maximal oxygen uptake (VO_{2max}) of soccer players

The maximal oxygen uptake is the highest value of VO_2 attained during exercise, usually over a 20 to 30 sec period (Carling, et al., 2009). The aerobic capacity VO_{2max} represents the metabolic parameter that quantifies the maximal oxygen uptake of an individual and is an important performance indicator in soccer (Da Silva, et al., 2008). In general, the wide-range that recorded of VO_{2max} in high level soccer players is between 55 and 70 $ml \cdot kg^{-1} \cdot min^{-1}$ (Al-Hazzaa, et al., 2001; Bangsbo, et al., 1991; Casajus, 2001; Stolen, et al., 2005).

Therefore, it is suggested that players should have VO_{2max} values superior to 60 $ml \cdot kg^{-1} \cdot min^{-1}$ in order to be competitive at the highest levels in soccer (Reilly, et al., 2000), although it is important to note that this is not a limiting factor to successful performance for soccer players.

VO_{2max} values for elite soccer players may be influenced by different styles of play, training regimes or phase of season (Ostojic, 2000). Given that the aerobic system is the main source of energy during soccer match play, teams with superior aerobic fitness may have an advantage, by being able to play the game at a faster pace throughout (Bangsbo & Lindquist, 1992).

(Wisloff, et al., 1998) supported the relationship between VO_{2max} and success in soccer game by demonstrating a clear difference in VO_{2max} between two top teams from the Norwegian elite division. Rosenborg, is the most successful team in Norway league recorded mean VO_{2max} of 67.6 $ml \cdot kg^{-1} \cdot min^{-1}$, and a lower placed team Strindheim recorded mean VO_{2max} of 59.9 $ml \cdot kg^{-1} \cdot min^{-1}$ in the top Norwegian division.

(Helgerud et al., 2001) stated that, increasing VO_{2max} increases the distance covered during a match and has also been linked to a corresponding 25% increases in ball involvements and 100% increase in number of sprints performed. The authors found that after an 8-week period of intense aerobic conditioning, VO_{2max} increased from $58.1 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ to $64.3 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$. Video analysis demonstrated that this increased aerobic capacity was associated with an increase from 8.619 ± 1.237 to 10.335 ± 10.335 m in the distance covered by players during the match.

(Wisloff, et al., 1998) confirmed the findings of (Helgerud, et al., 2001) and suggested that, if the average VO_{2max} in a team was $6 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ greater than their opponents it would be equivalent to having an extra player on the field in terms of the distance covered. This study also reported that the highest average VO_{2max} of a professional soccer team recorded to date was $67.6 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$. It is clear that the aerobic component of soccer training is of vital importance for success and should be monitored throughout the season.

Determining VO_{2max} of soccer players is therefore useful when assessing talent, in selection of players, in the design of physical conditioning programmes, predicting and monitoring physical match performance. Therefore, establishing reference parameters in high performance can assist in making important informed decisions, particularly for the physical fitness coaches at soccer clubs and National teams to manipulate physical training to optimize the regimes (Da Silva, et al., 2008).

Therefore, (Hoff & Helgerud, 2004) found VO_{2max} to be sensitive to soccer specific endurance training programmes. Similarly, (Svensson & Drust, 2005) surmise that VO_{2max} can be used to monitor improvements in training, differentiate players of different abilities and playing positions. Several previous studies have reported data of VO_{2max} values from First Division soccer players of high level teams (Al-Hazzaa, et al., 2001; Casajus, 2001; Hoff & Helgerud, 2004; Tumilty, 1993; Wisloff, et al., 1998). From these data, it appears that players have increased aerobic capacity in these European studies in recent years.

Thus, the following table demonstrates the mean of VO_{2max} in previous studies, which reported VO_{2max} in elite and professional soccer players. These data suggest that VO_{2max} may be useful in differentiating between successful and unsuccessful teams from countries, as teams who perform better in specific league or at a higher standard possess higher VO_{2max} .

Tab. 23: Maximal oxygen uptake (VO_{2max}) in elite and professional soccer players (mean \pm SD) according to (Carling, et al., 2009; Da Silva, et al., 2008)

References	Year	Nationality	Level	VO_{2max} $ml \cdot kg^{-1} \cdot min^{-1}$
Mercer et al.	1995	British	Professional	62.6 \pm 3.8
Urhausen et al.	1996	German	Professional	59.5 \pm 4.8
Raastad et al.	1997	Norwegian	Professional	62.8 \pm 4.1
Wisloff et al.	1998	Norwegian	Professional	67.6 \pm 4.0
Puga et al.	1998	Portuguese	Professional	59.6 \pm 7.7
Da Silva et al.	1999	Brazilian	Professional	52.5 \pm 7.5
Aziz et al.	2000	Singaporean	National	58.2 \pm 3.7
Al-Hazzaa et al.	2001	Saudi Arabian	Professional	56.8 \pm 4.8
Casajus	2001	Spanish	Professional	66.4 \pm 7.6
Helgerud et al.	2001	Norwegian	Professional	64.3 \pm 3.9
Dowson et al.	2002	New Zealand	National	60.5 \pm 2.6
Strudwick et al.	2002	British	Professional	59.4 \pm 6.2
Edwards et al.	2003	British	Professional	63.3 \pm 5.8
Wisloff et al.	2004	Norwegian	Elite	65.7 \pm 4.3
Brick et al.	2005	Ireland	Professional	51.3 \pm 4.4
Clark et al.	2007	South African	Professional	53.5 \pm 4.8
Di Silva et al.	2008	Brazilian	Professional	56.6 \pm 5.0
Caldwell et al.	2009	British	Professional	58.0 \pm 1.9
Sporis et al.	2009	Croatian	Elite	60.1 \pm 2.3
Boone et al.	2011	Belgian	Elite	57.7 \pm 4.7
Present Study		German	Professional	52.2 \pm 3.1

Previous studies in Tab. 23 reported mean VO_{2max} of elite and professional soccer players between 51-67 $ml \cdot kg^{-1} \cdot min^{-1}$. The results of VO_{2MAX} in previous studies in above table of German soccer players suggest that they possess lower levels of aerobic endurance than players from other countries, particularly in Europe. With respect to the time of aerobic endurance test in current study for soccer players, the wide difference may be due to a several factors such as total training time for improving aerobic capacity, total covered distances in soccer game and the different training procedures. It must be taken in considerations that different style of play and total covered distance related significantly with aerobic endurance capacity.

This difference was highlighted by who reported a mean total distance of 8.638 ± 1.158 m covered by (Rienzi, et al., 2000) players in the Copa America, was significantly lower ($p < 0.05$) than the mean total distance covered by players from the English Premier League 10.104 ± 703 m. In field team sports as soccer, VO_{2max} values of heavier players tend to be underestimated whereas values tend to be overestimated in players with a lower body mass (Svensson & Drust, 2005).

In context of player positions in soccer (Strudwick, et al., 2002) reported that, there is evidence that VO_{2max} varies according to positional role and the variability that observed in their study may be a result of positional specificity. The VO_{2max} of 19 professional players in the Portuguese first division was below $60 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ for goalkeepers and central defenders and above $60 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ for midfield players and forwards (Puga et al., 1993).

The following table demonstrates the previous studies of (Boone, et al., 2011; Wisloff, et al., 1998) who investigated the difference of VO_{2max} between elite soccer player positions. In study of (Wisloff, et al., 1998) participated twenty-nine elite soccer players, who categories as defenders ($n = 13$), midfielders ($n = 7$) and attackers ($n = 9$), while (Boone, et al., 2011) has categorized the players positions as goalkeepers ($n = 17$), centre-backs ($n = 60$), full-backs ($n = 82$), midfielders ($n = 68$) and strikers ($n = 62$).

Tab. 24: Comparison maximal oxygen uptake (VO_{2max}) between players positions in elite soccer players (mean \pm SD) (Boone, et al., 2011; Wisloff, et al., 1998)

Player positions	Maximal oxygen uptake (VO_{2max}) ($\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$)	
	(Wisloff et al. 1998)	(Boone et al. 2011)
Goalkeepers	---	52.1 ± 5.0^D
Centre-backs	---	55.6 ± 3.5^C
Full-backs	---	61.2 ± 2.7^D
Defenders	61.5 ± 3.3	---
Midfielders	66.4 ± 5.7^A	60.4 ± 2.8^D
Attackers	63.5 ± 3.5	56.8 ± 3.1^C

^a significantly higher than midfielders; ^(b, c, d) significantly differences between player positions; and the same ^(b, c, d) show no differences between player positions ($p < 0.05$)

The results of (Wisloff, et al., 1998) showed that midfield players had significantly higher VO_{2max} compared with defense and attack players. While results by (Boone, et al., 2011) showed that full-backs and the midfielders had a higher VO_{2max} compared to the attackers ($p < 0.05$) and centre-backs ($p < 0.01$), which in turn had a higher VO_{2max} than the goalkeepers ($p < 0.05$).

Generally, the review results of previous studies in Tab. 24 indicated that, midfield players had higher aerobic endurance capacity than other player positions. A significant correlation between VO_{2max} and distance covered during a match has been reported by (Reilly, 1996). Players with a higher VO_{2max} also carry out the highest number of sprints and take part more often in decisive situations during a match than those with lower values (Bangsbo, et al., 1991; Tumilty, 1993).

The higher VO_{2max} mean value of midfield players than other player positions may be due to the total covered distance. This findings also reported in study by (Di Salvo, et al., 2007) who reported more total covered distance for midfield players than other player positions. Therefore, the increased distance covered by midfield players may reflect more moderate intensity activity over long periods during the soccer game, which may indicate that midfield players require a more aerobic endurance capacity when compared to other positions.

2.2.4.3 Endurance characteristics of rugby players

Rugby union is a contact team sport that requires a variety of physiological requirements due to the high intensity nature of the sport, which involves short repeated sprints to high degrees of strength expression through high frequency contact (Deutsch, et al., 2007; Duthie, et al., 2003). The majority of field sports such as rugby union involve relatively short high-intensity bouts of exercise 5-25 sec coupled with lower intensity exercise or rest of up to 40 sec (Nicholas, 1997).

Rugby players require different types of endurance. To last 80 minutes of the game, to recover between intervals of play, to possess and maintain a high work

rate he needs good aerobic endurance that is the process of taking in, transporting and using oxygen to provide energy in the muscles (Taplin, 2005).

In context of rugby union game, (Bompa & Claro, 2009) suggested that 60% of the necessary energy for the game is supplied by the aerobic system, although most of the energy supplied during the actual ball in play time between 35 and 45% at professional level will be through the anaerobic system. (Kamenju et al., 2006) indicated that the 80 minute duration of a game requires rugby players to have a good aerobic fitness base, to help sustain a large cardiac output for a player to repeatedly engage in the start and stop activities of the rugby game.

(Bompa & Claro, 2009) stated that the high aerobic capacity, also known as VO_{2max} or the maximum volume of oxygen a player can bring to the muscle during efforts or recovery periods. Therefore, aerobic endurance is one of the important factors that determine the ability of rugby players to exercise for a long time without fatigue.

(Kamenju, et al., 2006) suggested that, many factors such as tactical considerations, interplay of players in tactical moves, proficiency in basic skills and those that are specific to the positional role determine a teams performance in rugby union. However, VO_{2max} comes in handy since without the ability to sustain the whole game duration skills, tactics and strategies remain underutilized.

A good indicator of a rugby player endurance capacity is the measurement of VO_{2max} (Taplin, 2005). Therefore, the aerobic endurance capacity will be used in current study to establish normative data for coaches and players, which allowing them to understanding the effects of covered distance and VO_{2max} throughout a rugby union game, as a major role factors in successful professional rugby players.

2.2.4.3.1 Covered distance of rugby players

The demands of rugby union game have been primarily reported with the use of time motion analysis and more recently global positioning systems (Cunniffe, et al., 2009; Deutsch, et al., 2007; Duthie, et al., 2006). Motion analysis using

(GPS) technology system provides an objective method to evaluate training loads, activity profiles of rugby players in the game and provides information that can be used in the design of physical conditioning programmes and testing protocols (Cunniffe, et al., 2009; Deutsch, et al., 2007; Deutsch et al., 1998).

Recent research has shown the total covered distances during a rugby union match in high performance players in range from 5.408 to 7.227 m (Cunniffe, et al., 2009; Roberts, et al., 2008). These covered distance are relatively low compared with the range of 7 to 13 km typical of elite soccer players (Stolen, et al., 2005). This finding difference is in line with comparable studies of (Duthie, et al., 2003; Reilly, 1997) for rugby players, who state in his research that Canadian rugby players spent about 85% of their time in low-intensity activity and 15% in high-intensity.

The covered distance during rugby union game has also been related to the level of competitions. (Roberts, et al., 2008) reported mean covered distance about 5.854 m of elite English players, while players at low level U19 covered mean distance about 4.940 m (Deutsch, et al., 1998). Key information on the game demands of rugby union not only focuses on movement patterns, but also relates to differences between players in various positions (Roberts, et al., 2008).

Back players covered distance more than forwards, which can be attributed to significantly greater distances walking and performing high-intensity running (Austin, et al., 2011; Roberts, et al., 2008). The differences may be due to the inside backs and centers continually realigning into defensive and offensive positions within the backline, and the outside backs involved in cover defense. The forwards however are involved in a greater amount of static exertion, indicated by a significantly greater time and frequency of scrums, tackles and rucks than the backs (Deutsch, et al., 2007; Roberts, et al., 2008).

The total distance covered by both forwards (5.581m) and backs (6.127m) during a 80 minute rugby match at the elite level (Roberts, et al., 2008) is in line with U19 age group level of forwards (4.240m) and backs (5.640m) during a 70

min match (Deutsch, et al., 1998). The difference in total distance traveled by backs and forwards is attributed to a greater walking distance by backs (2351 vs. 1928 m) and as result of high intensity running (448 vs. 298m) (Roberts, et al., 2008).

The following table presents the few studies, which investigated the total covered distances by elite and professional rugby players as an attempt to establish a normative data for coaches and rugby players.

Tab. 25: Total mean covered distance by elite and professional rugby players

References	Year	Nationality	Level	Covered Distance* (m)
Reid et al.	1974	British	Professional	3.470
Williams	1976	British	Professional	4.650
Roberts et al.	2008	British	Elite	5,854
Cunniffe et al.	2009	British	Elite	6.953
McLellan et al.	2011	Australian	Elite	5.278
Austin et al.	2011	Australian	Professional	5,198
Austin et al.	2012	Australian	Professional	6.796

* Covered distance based on mean of backs and forwards players

Few previous studies in Tab. 25 reported mean total covered distances between 3-6 km in elite and professional rugby players during matches. It may be that differences between previous studies related to the physical profile of players and nature of the game. Furthermore, different analysis systems are largely dependent on trained users and considerable subjectivity may exist when interpreting data.

In context of rugby player positions, (Roberts, et al., 2008) have analyzed the matches during 2 seasons in English rugby Premiership. In this study, participated twenty-nine elite rugby union players and were analyzed by using five video cameras. In addition, (Cunniffe, et al., 2009) have distinguished the match activity profiles of 2 elite rugby players that competed in the Celtic league and Guinness Premiership using a Global Positioning System (GPS) software. The following table demonstrates the total covered distances results, which reported by both studies for elite rugby player positions.

Tab. 26: Comparison covered distances in rugby union match between player positions of elite rugby players (mean \pm SD) (Cunniffe, et al., 2009; Roberts, et al., 2008)

Player positions	Total covered distance (m)	
	(Roberts et al. 2008)	(Cunniffe et al. 2011)
Backs	6.127 ^a	7.227 ^b
Forwards	5.581	6.680

^a significant difference between positions by (Roberts et al. 2008) and

^b significant difference between positions by (Cunniffe et al. 2011). ($p < 0.05$).

The results in previous studies in Tab. 26 indicated that back players had significantly total covered distance than forward players. These results also consisted in line with results of (Austin, et al., 2011; Deutsch, et al., 1998). The difference in total covered distance by backs and forwards may be caused to the demands role rugby game. Back players spent more distance in sprinting and working with most times at high-intensity running than forward players.

Sprinting data show that outside backs 280 ± 185 m sprint significantly greater total distances than inside backs 124 ± 78 m, tight forwards 144 ± 189 m and loose forwards 192 ± 203 m (Roberts, et al., 2008). The greater sprints performed by outside backs reinforces the generally accepted notion that as “finishers” they require a superior sprinting ability then other positional groups.

(Deutsch, et al., 2007) analyzed rugby players in six professional rugby matches, indicating the time spent on different types of match activities. The study indicated that during the whole match time, 12-13% for forwards of which 80-90% high-intensity activities were scrumming, rucking and mauling and 4.5% for back players of which 60-70% were in the form of cruising and sprinting.

Therefore, forwards tend to spend more time in physical contact and static exertion activities than backs, which spend more times than forwards in high-intensity free running. This demands game role of back players clear the greater covered distance in matches, when compared to forward players. It could be said also that back players need more aerobic capacity than forward players, this findings should be taken in consideration for specifications training programmes between training groups.

For this purpose, (Welsh, WRU) has indicated that aerobic training programmes should involve a series of timed measurable activities. Players should try to reduce the time taken to achieve the specific distance or increase the distance covered in a set time.

2.2.4.3.2 Maximal oxygen uptake (VO_{2max}) of rugby players

The development of VO_{2max} is important for rugby players to manage with the increased level of fatigue during the game. It is important for rugby players to be able to provide the largest amount of oxygen to the muscles as possible during rest time to compensate for oxygen debt. This can only be achieved through a maximum development of oxygen intake, enhanced by a well developed cardiovascular system (Bompa & Claro, 2009).

(Welsh, WRU) demonstrated the physiological benefits of aerobic endurance training for rugby players:

- Aerobic endurance can serve as a base for players to work from and develop other components of fitness.
- Aerobic endurance accelerates the rate of recovery in rest periods during the game and after intensive training and matches.
- By delaying the onset of fatigue it will help maintain concentration, focus and decision making for players.

In addition, (Bompa & Claro, 2009) suggested that, a good aerobic endurance also has the benefit of facilitating a players recovery during training, between training sessions, and during a stoppage in the game. This is advantageous since a highly recovered player can continue to play with higher intensity.

(Duthie, et al., 2003) recorded wide-range of the moderate aerobic endurance capacity in rugby players between 50 to 60 $ml \cdot kg^{-1} \cdot min^{-1}$ and suggest that this component is one important factor of several requirements of the overall fitness profile for rugby players. However, (Bompa & Claro, 2009) Indicated that rugby players who willing to achieve high performance levels should have a VO_{2max} of around 60 $ml \cdot kg^{-1} \cdot min^{-1}$.

High aerobic endurance capacity (indicated by a high VO_{2max}) accelerates the recovery from repeated high-intensity efforts (Bompa & Claro, 2009). Comparable study for rugby players of (Duthie, et al., 2003) has been suggested that the achievement of a high VO_{2max} in rugby may not be a priority compared to other sports such soccer that related positively to the covered distance and level of work intensity, number of sprints and involvements with the ball (Helgerud, et al., 2001).

In context of comparisons to field sports, (Duthie, et al., 2003) have been reported that the VO_{2max} of international rugby forward players $51.1 \pm 1.4 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ is lower than players from more running field sports such as soccer $57.8 \pm 6.5 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ and field hockey players $61.8 \pm 1.8 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$. The maximal oxygen uptake VO_{2max} was used to distinguished level between rugby players, (Nicholas & Baker, 1995) have examined the mean of VO_{2max} using shuttle run test for first and second class rugby players that recorded mean of 54.05 and 55.50 $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$.

There are several studies have used shuttle run test as a predictor test for VO_{2max} . (Gabbett, 2002a) has compared the aerobic endurance capacity between first and second Australian rugby league players. The results of his study reported non-significant difference between first and second grade players in VO_{2max} , 46.8 ± 4.2 and $45.2 \pm 4.5 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$, respectively. In this study also author has distinguished amateur, semi-professional and professional players and reported VO_{2max} mean values of 39.0 ± 5.3 , 46.0 ± 4.4 and $53.2 \pm 4.5 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$.

Differences between positions and levels are similar to those for other physical characteristics. Multiple studies have found significantly greater VO_{2max} or shuttle run performance in elite or senior players compared to sub-elite or junior players (Gabbett, 2002a, 2002b; Quarrie, et al., 1995). It is thought the lower fitness is representative of a lower relative training and playing frequency and intensity of the lower playing levels (Gabbett, 2000).

Thus, maximum oxygen uptake expresses the physical capacity of a player and can be used for comparisons across playing levels and sports. However, the shuttle run test as a field test that reviewed above may not accurately express the ability to perform prolonged intermittent exercise with alternating intensities as is required for rugby union. (Svensson & Drust, 2005) suggested that, maximal oxygen uptake may not be a sensitive enough indicator of fitness for regular use within the competitive season when changes in physiological systems and in performance will be small.

A related aerobic endurance capacity test 3-km timed run is described for international rugby players by (Carling, et al., 2009; O’Gorman et al., 2000; Taplin, 2005; Welsh, WRU). This procedure involves the completion of 7.5 laps on a 400m running track. (Welsh, WRU) has been used formula to predicted VO_{2max} by the distance and time that recorded from a player who completed the total distance of 3-km run test. This predicts formula has been used in current study to estimate the VO_{2max} for international rugby players and outlined in the next chapter.

(O’Gorman, et al., 2000) have examined the validity of field tests for evaluating endurance capacity in international rugby players. The authors reported that, 3-km run test appear to be valid predictors of VO_{2max} for international rugby players and was significantly correlated ($r = -0.67$, $p < 0.05$) with direct VO_{2max} test by graded treadmill and showed to be interrelated ($r = -0.96$).

(Welsh, WRU) classified the best and poor time that recorded of players when completed 3-km run test, 11.50 and 12.50 min, respectively. (Taplin, 2005) Indicated that amateur male rugby players who willing to achieve high performance levels should record time between 12.30 to 14.00 min.

The following table includes studies published from the recent years, which measured estimated VO_{2max} in elite and professional rugby players. These data were compiled with VO_{2max} data that collected in current study to contribute specific table of updated normative values.

Tab. 27: Maximal oxygen uptake (VO_{2max}) in elite and professional rugby players (mean ± SD)* according to (Duthie, et al., 2003; Nicholas, 1997; Reilly, 1997)

References	Year	Nationality	Level	VO _{2max} ml·kg ⁻¹ ·min ⁻¹
Ueno et al.	1988	Japanese	Professional	54.8 ^a
Jardine et al.	1988	South African	Professional	53.9 ^a
Menchinelli et al.	1992	Italian	Professional	61.9 ± 7.1 ^a
Holmyard et al.	1993	British	International	58.4 ± 3.3 ^b
Nicholas et al.	1995	British	Professional	54.05 ^b
Tong et al.	1995	British	Elite	55.65 ^b
Deutsch et al.	1998	British	Elite	52.7 ^a
O'Gorman et al.	2000	Ireland	International	54.1 ± 1.4 ^a
Brick et al.	2005	Ireland	Professional	56.85 ^b
Cunniffe et al.	2009	British	Elite	53.3 ± 2.1 ^c
Present Study		German	Professional	53.8 ± 3.40

*VO_{2max} without (SD) based from mean value back and forward players; ^a VO_{2max} of treadmill test; ^b VO_{2max} of shuttle run test 20m and ^c VO_{2max} of heart rate memory belt

Previous studies in Tab. 27 reported range mean of VO_{2max} in elite and professional rugby players between 52-61 ml·kg⁻¹·min⁻¹. The mean value VO_{2MAX} in current study of German rugby players suggest that they not wide from rugby players in other countries, with respect to different methods that measured maximal aerobic endurance capacity. In addition, the small wide difference between rugby players over recent years may be due to a several factors such as total training time for improving aerobic capacity and the different training procedures.

It is important to establish normative data, which needed for the various positions in order that players have targets at which to aim. The following table presents the previous studies, which have examined the maximal oxygen uptake VO_{2max} difference between back and forward positions in elite and professional rugby players.

Tab. 28: Comparison maximal oxygen uptake (VO_{2max}) between player positions in elite and professional rugby players (mean ± SD)* (Nicholas, 1997; Reilly, 1997)

References	Year	Nationality	Level	VO _{2max} (ml·kg ⁻¹ ·min ⁻¹)	
				Backs	Forwards
Jardine et al.	1988	South African	Prof	55.8 ^a	52.0 ^a
Nicholas et al.	1995	British	Prof	56.3 ^b	51.8 ^b
Tong et al.	1995	British	Elite	59.1 ± 2.8 ^b	54.3 ± 3.1 ^b
Brick et al.	2005	Ireland	Prof	59.6 ± 4.7 ^b	54.1 ± 2.6 ^b

*VO_{2max} without (SD) not available; ^aVO_{2max} of treadmill test and ^bVO_{2max} of shuttle run test 20m

The results in Tab. 28 indicates, that back players had higher VO_{2max} mean range value than forward players $55-59 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ and $51-54 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$, respectively. This overview of rugby player positions indicates, that backs had greater VO_{2max} value $\sim 5 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ than forwards, and consisted with finding results of (Maud, 1983; Tong & Mayes, 1997). In addition, (Duthie, et al., 2003) in their comparable physiology research for rugby union showed that forward players have values ranging from 44 to 55 $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ whereas back players range from 47 to 60 $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$.

The difference in aerobic endurance capacity between back and forward players may be related to total covered distance and role tactics in rugby game. Back players spent more distance in sprinting and working with most times at high-intensity running than forward players. This finding should be taken in consideration when plan training programmes in small groups for rugby players.

2.2.5 Summary

The aims of this theory review were to establish the differences in physical fitness characteristics between soccer and rugby players as a popular field team sports around the world, discuss the relationship between physical characteristics and establish the effectiveness of physical training programmes in elite and professional levels.

While the primary focus of this review is within the sport of rugby union, due to limited literature in aspects of physical fitness, other related sports, such as rugby league and rugby sevens, have been included to further substantiate conclusions. Nonetheless, from the theory literature reviewed of similar contact field team sports, it clear that differences in physical characteristics occur between positions, demonstrating the heterogeneous nature of the positions and the roles they play within teams. The differences between competition levels and player positions may be partially based on physique and physical performance factors. Future research should therefore employ programmes that take these differences in consideration.

3. Methodology

This chapter will demonstrate the details of methods and procedures that used in this study. Firstly the research and study design adopted is described followed by the characteristics of the participants comprising the study sample. An explanation of the processes used in conducting the research data collection as well as giving a full description of the methods and procedures of each assessment that was included in the test battery conclude the chapter.

3.1 Research design

A quantitative approach was used in this study with the specific nature of the research design being exploratory, descriptive and comparative in nature. The study was exploratory as it aimed to achieve new insights into the anthropometric and physical fitness characteristics of high elite players in Germany and to determine priorities for future research. The study is also classified as descriptive, as it aimed to portray accurately the characteristics of the particular study subjects during a preparation period to second phase of competition season, as well as being comparative, in order to firstly compare the soccer and rugby players scores and secondly to compare the study data with the previous results of similar studies involving players at elite and professional levels in soccer and rugby union.

3.2 Participants

Subjects were twenty-eight soccer and rugby professional players. Both field team sports playing at high-level competitions. All information, details and procedures about this study were given to participants in the study. All descriptive data of the subjects are presented in the following Tab. 29:

Tab. 29: Descriptive mean \pm SD of participants

Variables	Soccer (n = 14)			Rugby (n = 14)		
	Mean \pm SD	Min	Max	Mean \pm SD	Min	Max
Age (year)	24.57 \pm 4.33	19	31	24 \pm 3.94	18	32
Height (m)	1.85 \pm 0.07	1.70	1.95	1.81 \pm 0.05	1.73	1.90
Body weight	83.86 \pm 8.5	68	99.60	91.05 \pm 12.16	73.50	118.9
Body mass index (kg m ⁻²)	24.50 \pm 1.45	22.13	27.30	27.77 \pm 2.33	24.16	32.94

Financial support was obtained by the research center for performance diagnostics and training advice (FLT) at university of Wuppertal, Germany. The Human Subject Ethics Committee of the University of Wuppertal approved all procedures undertaken in this study.

3.3 Study design

The aims of this study was to investigate the difference in physical fitness characteristics between soccer and rugby players, to establish a profile for both field team sports players, and using a performance tests battery to assess the physical fitness characteristics in accordance with research literatures.

Two field team sports involved in this study, the first sample was soccer professional team who playing in the Bundesliga and Europe Champions league. The second sample was German international rugby union team who playing in Bundesliga and qualification Europe champions. Measurements were performed on thirty-four professional players; six of these participants were rejected as a result of screening for pre-existing injuries that would inhibit their participation in the study.

Testing time for soccer and rugby players was performed during the break period between first and second season phases and about one month before the beginning second phase in season. The length of the break period between first and second phases season was about 6 weeks for soccer players and 10 weeks for rugby players. The competitive season phases, timing schedule of season periods and testing sessions presented in the next following table:

Tab. 30: Timing schedule of the season periods and testing sessions for soccer and rugby players

Season phases	Season 2007/2008	
	Soccer	Rugby
In season (Phase 1)	10.08.07 - 16.12.07	25.08.07 - 07.12.07
Season break	17.12.07 - 31.01.08	08.12.07 - 07.03.08
In season (Phase 2)	01.02.08 - 17.05.08	08.03.08 - 17.05.08
Testing session	05.01.2008	08.02.2008

The performance tests were anthropometry (height and body weight), speed (sprint 5 m, 10 m and 30 m), change direction (FLT Z-Run Sprint) test, strength

(1RM bench press and back squat) and endurance were two tests for maximal aerobic capacity to estimated VO_{2max} (3-km run) as a field test for rugby players and (incremental FLT VO_{2max}) test on a motorized treadmill as laboratory test for soccer players using the protocol of research center for performance diagnostics and training advice (FLT) at the University of Wuppertal. All test variables that involved in this study are listed in the following table:

Tab. 31: Performance test variables

Test category	Kind	Parameters	Unit
Personal data		Age	Year
Anthropometry	Body profile	Height	Meter
Anthropometry	Body profile	Body weight	Kilograms
Anthropometry	Body profile	Body mass index	$kg \cdot m^{-2}$
Speed	Linear sprint	5m	Second
Speed	Linear sprint	10m	Second
Speed	Linear sprint	30m	Second
Speed	Non-linear sprint	8m	Second
Speed	Non-linear sprint	15m	Second
Speed	Non-linear sprint	22m	Second
Speed	Non-linear sprint	1.Ch	Second
Speed	Non-linear sprint	2.Ch	Second
Strength	Upper body	1RM bench press	Kilograms
Strength	Lower Body	1RM back squat	Kilograms
Endurance	Treadmill	VO_{2max}	$ml \cdot kg^{-1} \cdot min^{-1}$
Endurance	Field	3-km run	Minute

In order to use performance tests as one of the most common and important measures, which used in sports science. There are three main criterion factors (objectivity, reliability and validity), which need to be considered when deciding which performance protocol should be used. Objectivity is quantified by calculating the correlation between pairs of test scores measured on the same individuals (Heyward, 2006), validity refers to the degree to which a test or test item measures what it is supposed to measure (Baechle & Earle, 2008; Thomas, et al., 2011) and reliability is a measure of the degree of consistency or repeatability of a test. If a player whose ability does not change is measured two times with a perfectly reliable test, the same score is obtained both times (Baechle & Earle, 2008).

The main quality criterion of objectivity was met by standardized conditions. For example, all tests completed in the same order, rest period between tests

identical for each player in length, test instructions informed for all players and the communication has been reduced between the test managers and players as much as possible. In addition, the performance tests underwent to the reliability requirements, which used same equipments, materials, test places and test managers if tests repeated again. Furthermore, the tests battery will be highly valid when performance test batteries represent quantified data that measured for.

All performance tests that used in this study have been underwent to the main quality criterion. The staff in research center for performance diagnostics and training advice (FLT) of University of Wuppertal had examined the quality criterion for all tests. Pearson product-moment correlation coefficients were used to determine the relationships between performance tests data during break period in year 2008 and 2009. The following table presents the correlation coefficient between the mean of two best trials.

Tab. 32: Correlation coefficient between tests data in seasons 2008 and 2009

Variables	Correlation coefficient pre-post tests in 2008 - 2009
Sprint 5m (sec)	0.591*
Sprint 10m (sec)	0.825**
Sprint 30m (sec)	0.877**
Sprint FLT Z-Run 8m (sec)	0.516*
Sprint FLT Z-Run 15m (sec)	0.814**
Sprint FLT Z-Run 22m (sec)	0.897**
Sprint FLT Z-Run 1.Ch (sec)	0.496*
Sprint FLT Z-Run 2.Ch (sec)	0.693*
Endurance treadmill VO_{2max}	0.929**

1.Ch = First change direction time

2.Ch = Second change direction time

* $p \leq 0.05$

** $p \leq 0.01$

The staff of research center for performance diagnostics and training advice (FLT) of University of Wuppertal had designed the (FLT Z-Run Sprint) to measure non-linear speed. Strength tests for upper and lower body (1RM bench press and back squat) are standardized tests and were conducted according to a recognized protocol in previous studies of previous studies in soccer (Hoff, 2005; Svensson & Drust, 2005; Wisloff, et al., 2004; Wisloff, et al., 1998) and

rugby (Appleby, et al., 2011; Argus, et al., 2009; Duthie, et al., 2003). As same as, endurance 3-km run test was conducted according to a recognized protocol in literatures of rugby players (O’Gorman, et al., 2000; Taplin, 2005).

The test battery and protocol in the study were selected after consulting the relevant literature, and identifying the tests that were previously conducted by researchers in similar studies on players at elite level in soccer and rugby. The tests that were selected are those that were considered to closely represent the required test scores in order to meet the requirements of playing soccer and rugby in top-levels. These particular tests were also chosen so that the results of the study could be compared to other similar international researches.

3.4 Research procedures

Measurements were conducted over two days, which had been one day for each team. Soccer players measured on 05.01.2008 in their club in Gelsenkirchen which had an artificial turf hall, strength training room and performance diagnostic center that including 5 treadmill’s in laboratory. Rugby players measured on 08.02.2008 in Olympic training center in Heidelberg because most of rugby players came from several cities around Germany.

Anthropometrics measurements were collected for all players before testing session beginning. The testing sessions for soccer and rugby players were conducted on days that players informed before, and they didn’t underwent to any training exercises in the day of performance tests. All of the participants in this study were assessed during the appointed time (9am - 5pm) in alphabetical order, and this order was maintained during each testing day. All tests included in the test battery were performed on each participant in the same order.

Testing session begin with sprint (5 m, 10 m and 30 m) test followed by strength 1RM for upper body (bench press) and lower body (back squat) and finished by endurance test. The procedure demands time and expensive equipment don’t allow to tested endurance for both teams with same method. The possibility provided an easy way for soccer players, who performed (VO_{2max}) endurance test in their club laboratory on a motorized treadmill according to test protocol

improved by (FLT) staff. These possibilities were not available for rugby players during test session, which completed (3-km run) test as recommended endurance field test for international rugby players with a predicted (VO_{2max}) method, that can be determined using formula described in the endurance test protocol section.

The following tables demonstrate the measurements alphabetical order that obtained from soccer and rugby players during a single testing session.

Tab. 33: Measurements order testing session for soccer players

Testing session for soccer players
Height and body weight tests
Warm-up and stretching (20 min)
Linear sprint (5 m, 10 m and 30 m) test
Non-linear sprint (FLT Z-Run Sprint) test
Bench press test
Back squat test
Incremental endurance VO_{2max} test

Tab. 34: Measurements order testing session for rugby players

Testing session for rugby players
Height and body weight tests
Warm-up and stretching (20 min)
Linear sprint (5 m, 10 m and 30 m) test
Non-linear sprint (FLT Z-Run Sprint) test
Bench press test
Back squat test
Endurance 3-km run test

When conducting each testing session a number of steps were undertaken to ensure that the results were valid and reliable. These procedures relating to the organization, administration and delivery of the tests are outlined below:

Pre-testing

- Club staff and players were informed as to the date, time and location of the testing,
- all equipment was checked in terms of calibration and electrical charge, and
- all assistants and helpers for the testing were fully briefed with regards to their roles during the tests.

During testing

- The principle and nature of the tests were introduced to the players (i.e. what it is; what it measures),
- the procedures and rules for each test were explained to the players prior to each respective test,
- each testing procedure was demonstrated to the players,
- the order of tests for each testing session was the same on each event and is outlined in the summary of the testing sequence below, and
- all physical performance testing scores were recorded on a data collection sheet.

Testing sequence summary

- The warm-up duration was 20 minutes involved jogging, stretches and sprinting,
- prior to each test session, players completed a standard warm-up, which consisted of joining about 5-7 minutes following by a different series of stretches for upper and lower body,
- players performed some sequences of linear sprint test (2 x 10 m and 20 m),
- after warm-up, players take 5 minutes rest period before they begin the linear sprint test,
- linear sprint test (3 x 5 m, 10 m and 30 m),
- 5 minutes rest periods between linear sprint test and non-linear (FLT Z-Run Sprint) test,
- players performed 2 X practice of non-linear sprint test (22 m) to identify the nature of the test,
- non-linear sprint test (2 x 8m, 15m and 22m),
- about 20 min rest periods, that allows the players to going to the strength room, which strength tests measured there,
- players performed specific stretches and the lifting of relatively light loads as a warm-up before strength tests,

- players were required to complete first a 1RM bench press and later back squat,
- warm-up loads kilograms and pauses between trials will be described in the testing section protocol,
- 10-20 minutes rest period between strength and endurance test,
- in testing session for soccer team, after strength test players going to the club laboratory, which will be tested endurance on a motorized treadmill to estimating the VO_{2max} , and
- in testing session for rugby team, players going to the 400 m track, which will be completed 3-km run test there.

3.5 Measurements and testing protocols

A detailed description of each test and measurement, as well as the procedures and equipment used in the test battery is provided in the following format:

- Purpose of tests
- Equipment used
- Procedure utilized
- Number of trials
- Scoring

3.5.1 Anthropometrics measurements

Prior to the start of each testing session a series of personal details and anthropometric measurements were collected from each subject and recorded. The first name, surname, date of birth and playing position of each player to take part in the testing session were recorded. The standing height of each player was measured without shoes and socks and for body weight; players wore only very light clothes (underpants and shorts). From the player standing height and body weight measurements, body mass index (BMI; kg m^{-2}) was calculated.

3.5.2 Linear sprint (5 m, 10 m and 30 m) test

Equipment

- Two split TDS ground contact plate 60 x 90 cabled, with
- TDS interface with 6 ports cabled, with
- 4 TDS double light barriers with 8 reflectors (© TDS Werther sport company, Austria)
- 1 laptop
- 8 stands
- 2 pylons

Test procedure

The player stand with back foot on the start contact plate and the front foot up to the starting line that pointed 40 cm away from the contact plate. After the test conductor give a start signal, the player can determine the start of the test by himself. It doesn't give any other signal to start the test. The player starting the sprint test from the standing position and sprint as fast as possible through the double light barriers. There are two pylons positioned 3 meters away from the last double light barriers, which player must be run through them. The player must be completed the 30 m sprint test without any breaking or slow down before reached the two pylons after the last double light barriers. The time starts when the back foot leaves the start contact plate. The total time recorded over three sprint distances 5 m, 10 m and 30 m. Each player completed 3 trials and the mean of two best times will be taken in the statistical analysis.

The following figure shows the structure of the linear sprint:

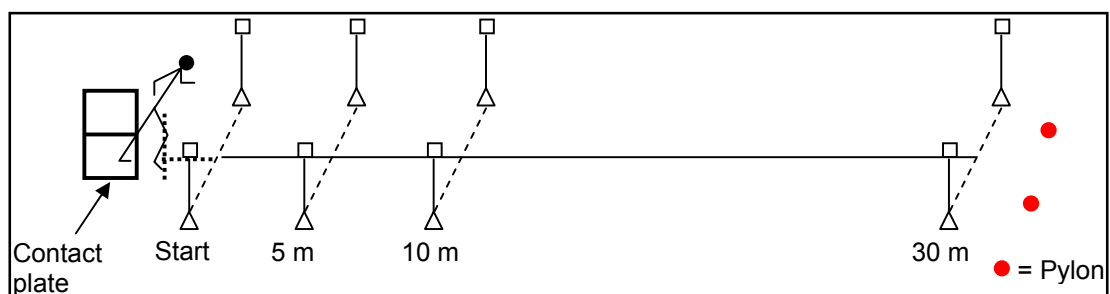


Fig. 4: Linear sprint test

3.5.3 Non-linear (FLT Z-Run Sprint) test

Equipment

- 4 HS double light barriers (© HS-electronics sport company, Germany)
- Receiver and sender Infrared transmitter, with
- Battery box and display unit
- 6 bars including stands
- 6 pylons
- 2 laptops
- Special software
- Tape

Test procedure

The player stands with front foot up to the starting line that pointed one meter away from the start double light barriers. After the test conductor give a start signal, the player can determine the start of the test by himself. It doesn't give any other signal to start the test. The player starting the sprint test from the standing position and sprint as fast as possible through the double light barriers. The player must be completed the 22 m non-linear sprint test without any breaking or slow down before reached the finish double light barriers. The time starts when the player runs through the first start double light barriers. The total time recorded over three sprint distances 8 m, 15 m and 22 m and 2 times turn with change directions (1.Ch and 2.Ch). Each player completed 3 trials and the mean of two best times will be taken in the statistical analysis.

The following figure shows the structure of the non-linear (FLT Z-Run Sprint) test:

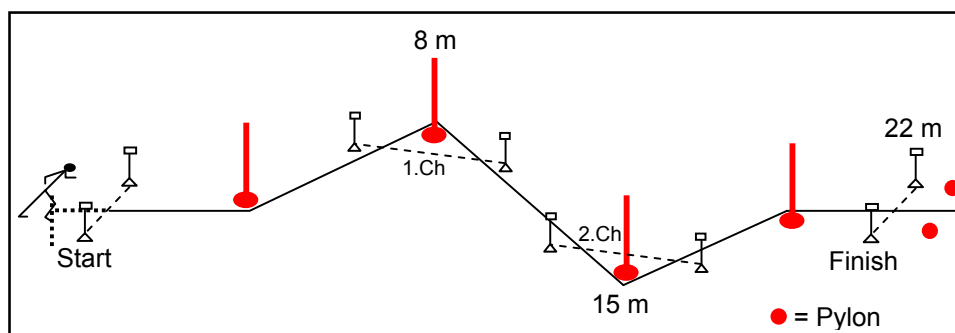


Fig. 5: Non-linear (FLT Z-Run Sprint) test

3.5.4 One repetition maximum bench press (1RMbp)

Equipment

- Olympic bar bench
- Bar weighed 20 kg
- Free different weights (2.5, 5, 10, 15, 20, and 25) kilograms

Test procedure

The (1RMbp) exercise is performed on a flat bench (free) with an Olympic bar with corresponding different weights. The aim of this test is to determine the one repetition maximum. The player performed warm-up with completed 6 repetitions at the first and followed by 4 repetitions. Player starts with a weight selected on the basis of previous bench press training loads, and lowered the bar down to the chest and then pushed the bar out until arms were fully extended. After a successful lift the weight was increased until players was unable to lift his maximum load in one repetition. Rest period between lifts was 3 minutes. The final weight lifted successfully is recorded as the absolute (1RMbp), while relative maximum strength was calculated by dividing (1RMbp) through the body weight of player.

The following figure shows the Olympic bar bench:



Fig. 6: Olympic bar bench



Fig. 7: Bench press test

3.5.5 One repetition maximum back squat (1RMbs)

Equipment

- Olympic barbell squat machine
- Squat machine (© gym80 sport company, Germany)
- Different weights (20, 25, and 50) kilograms

Test procedure

The 1RMbs (half-squat) exercise is performed with corresponding different weights. Player starts with a weight selected on the basis of previous training loads and performed warm-up with completed 6 repetitions at the first and followed by 4 repetitions. The player stands in the barbell stand in an upright position with feet positioned shoulder-width apart. The player descends to a knee angle of 90° of flexion legs and then returns to the start position. After a successful lift, the weight was increased until player was unable to lift his maximum load in one repetition. Rest period between lifts was 3 minutes. The final weight lifted successfully is recorded as the absolute (1RMbs), while relative maximum strength was calculated by dividing (1RMbs) through the body weight of player.

The following figures show the barbell stand devices that used for (1RMbs) for soccer and rugby players:



Fig. 8: Olympic barbell squat machine



Fig. 9: Squat machine gym80

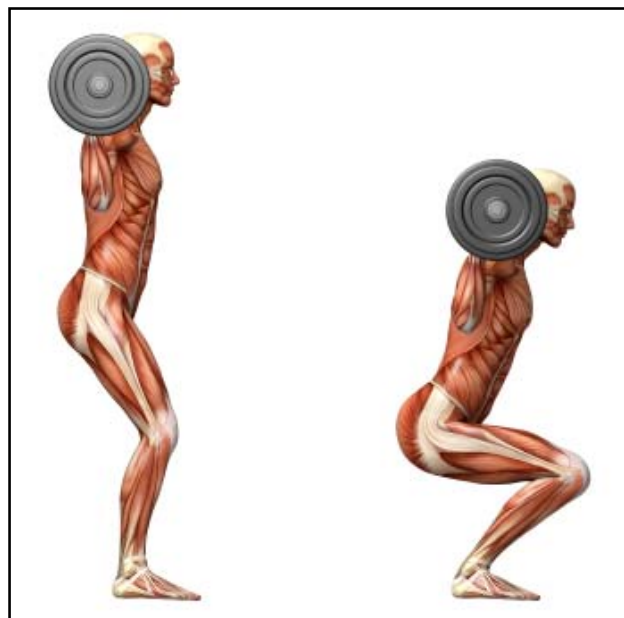


Fig. 10: Back squat 90° protocol test

3.5.6 Endurance tests

The aerobic endurance tests divided into 2 test protocols. Soccer players were tested in laboratory club on a motorized treadmill for estimating the VO_{2max} , while rugby players completed 3-km run field test in 400m track.

3.5.6.1 FLT (VO_{2max}) protocol test

Equipment

- H/P Cosmos motorized treadmill (©H/P Cosmos Sport Company, Germany)
- Power Cube-Ergo with flow sensor
- RS 232 - infrared interface for 4 KV separations between Power Cube and PC.
- O_2 and CO_2 analyzer

Test procedure

The Ramp-Test was performed on a motorized treadmill (H/P Cosmos Pulsar, Germany) in the laboratory. Oxygen uptake was measured using a breath-by-breath gas analyzing system (Ganshorn PowerCube-Ergo, Germany) and averaged over 10 s throughout the entire test. The gas analyzing system was calibrated with a calibration gas (15.5% O_2 , 5% CO_2 in N; Messner, Switzerland) and a precision 1-L syringe (Ganshorn, Germany) before each test. Following a 4 minutes run at $10 \text{ km}\cdot\text{h}^{-1}$ with 1% inclination, the inclination was increased to 5% for 4 minutes. The treadmill speed was then increased every 2 min by increments of $1 \text{ km}\cdot\text{h}^{-1}$ until player reached his exhaustion. The following figures show the devices that used in this protocol:



Fig. 11: H/P Cosmos motorized treadmill



Fig. 12: Power Cube-Ergo with flow sensor

3.5.6.2 Three kilometers field run test

Equipment

- 400 meter running track
- Stopwatch

Test procedure

The aim of this test is to complete a 3-km run course in the shortest possible time. At the start, all participants are to line up behind the starting line. On the command (go) the clock will start and the players begin running, at their own intensity. Walking is allowed, but not encouraged and after each lap, every player called to avoid confusion of distance remaining. The total time record when player finished the 3-km run test in minutes and seconds. A predicted VO_{2max} can be determined using special formula⁶.

3.6 Statistical analysis

All data were checked for normality with no need for further transformation using the nonparametric Kolmogorov-Smirnov test for normal distribution, while Levene test was used for homogeneity of variances. There were three trials for each player collected during the linear 30 m and non-linear (FLT Z-Run Sprint) sprint tests; the mean value of the two best trials of sprint times was collected for statistics. According to strength tests (1RMbp) and (1RMbs), the maximum final weight, which lifted successfully by a player was recorded and used for strength statistics. Maximum VO_{2max} mean value of soccer players used for endurance statistics, and the total end time of completed 3-km run test and estimated VO_{2max} were collected to use for endurance statistics for rugby players.

The data analysis of the study had the following aims:

- To determine if there is a significant difference between soccer and rugby players in anthropometrics and physical fitness tests.
- To determine the relationships between speed, strength and endurance variables for soccer and rugby union.

⁶ $VO_{2max} = ((2.9226 + (0.89 \times \text{km/h}^*)) \times 3.5)$ while, $\text{km/h} = (3.0/3000\text{m time in sec.}) \times 60 \times 60$ (Taplin, 2005; Welsh, WRU)

The statistical data analysis procedures that were used in this study included:

Descriptive statistics

Descriptive statistics are used to describe all data. The means, standard deviations, minimum and maximum scores for all variables measured were determined.

Independent t-test (Two independent samples)

This test is used to determine whether two samples differ reliable from each other. In this study it was used to determine whether any significant differences between soccer and rugby players in anthropometric and physical fitness characteristics.

Pearson correlation coefficients

Pearson correlations were used to determine the statistically significant relationships ($p < 0.01$; $p < 0.05$) between the different measurement variables in physical fitness performance.

SPSS statistics 17.0 was used for all statistical calculations. The level statistical significance was accepted at the 95% confidence interval of the difference and interpretation classified in the following table:

Tab. 35: Interpretation significant classifications at 95% confidence interval

Significant level	Interpretation
$p > 0.05$	no significant
* $p \leq 0.05$	significant
** $p \leq 0.01$	High significant

4. Results

This chapter describes the anthropometric and physical fitness characteristics for soccer and rugby players. It highlights the differences, which have observed between soccer and rugby players in speed, strength and endurance tests and also indicates which characteristics of the participants showed significant. In addition, this chapter also attempts to indicate which of the physical fitness characteristic variables related to each other in soccer and rugby union field team sports as important predictor for training consequences and identification sub-elite players.

4.1 Anthropometric and personal characteristics

Tab. 36 presents the descriptive and significant difference statistics in age, height, body weight and body mass index between soccer and rugby players.

Tab. 36: Anthropometric (mean \pm SD) and independent t-test (p) between soccer and rugby players

Variables	Sport	Mean \pm SD	Mean Difference	p
Age (y)	Soccer	24.57 \pm 4.33	0.57	0.72
Age (y)	Rugby	24.00 \pm 3.94		
Height (m)	Soccer	1.85 \pm 0.07	0.04	0.10
Height (m)	Rugby	1.81 \pm 0.05		
Body weight (kg)	Soccer	83.86 \pm 8.50	-7.19	0.08
Body weight (kg)	Rugby	91.05 \pm 12.16		
BMI (kg m ⁻²)	Soccer	24.50 \pm 1.45	-3.27	0.00**
BMI (kg m ⁻²)	Rugby	27.77 \pm 2.33		

** $p \leq 0.01$

There is no significant difference in age, height and body weight were found between soccer and rugby players ($p > 0.05$), although significant difference in (BMI) between soccer and rugby players was observed ($p \leq 0.01$). The highest mean in age and height were observed in soccer players, although the highest mean in body weight and body mass index were observed in rugby players.

4.2 Speed characteristics

The following tables present the descriptive and significant difference statistics in linear (5 m, 10 m and 30 m) sprint test and non-linear (FLT Z-Run Sprint) test.

4.2.1 Linear sprint

Tab. 37 presents the descriptive and significant difference statistics in linear (5 m, 10 m and 30 m) sprint between soccer and rugby players.

Tab. 37: linear 5 m, 10 m and 30 m sprint (mean \pm SD) and independent t-test (p) between soccer and rugby players

Variables	Sport	Mean \pm SD	Mean Difference	p
5m (sec)	Soccer	1.11 \pm 0.04	-0.11	0.00**
5m (sec)	Rugby	1.22 \pm 0.10		
10m (sec)	Soccer	1.85 \pm 0.05	-0.15	0.00**
10m (sec)	Rugby	1.99 \pm 0.12		
30m (sec)	Soccer	4.24 \pm 0.17	-0.34	0.00**
30m (sec)	Rugby	4.58 \pm 0.19		

** $p \leq 0.01$

The results demonstrates that, soccer players recorded faster mean times than rugby players in linear 5 m, 10 m and 30 m sprint distances and observed significant difference between soccer and rugby players ($p \leq 0.01$).

4.2.2 Non-linear sprint

Tab. 38 presents the descriptive and significant difference statistics in non-linear (FLT Z-Run Sprint) test over 8 m, 15 m and 22 m distances and (1.Ch and 2.Ch) directions sprint between soccer and rugby players.

Tab. 38: Non-linear (FLT Z-Run) sprint (mean \pm SD) and independent t-test (p) between soccer and rugby players

Variables	Sport	Mean \pm SD	Mean Difference	p
8m (sec)	Soccer	1.61 \pm 0.25	-0.06	0.41
8m (sec)	Rugby	1.67 \pm 0.09		
15m (sec)	Soccer	3.36 \pm 0.50	-0.45	0.00**
15m (sec)	Rugby	3.82 \pm 0.14		
22m (sec)	Soccer	5.43 \pm 0.80	-0.44	0.06
22m (sec)	Rugby	5.86 \pm 0.18		
1.Ch (sec)	Soccer	0.90 \pm 0.17	-0.12	0.03*
1.Ch (sec)	Rugby	1.02 \pm 0.10		
2.Ch (sec)	Soccer	0.86 \pm 0.14	-0.02	0.71
2.Ch (sec)	Rugby	0.88 \pm 0.11		

1.Ch = first change direction; 2.Ch = second change direction; ** $p \leq 0.01$ and * $p \leq 0.05$

There were no significant difference found in sprint 8 m, 22 m distances and 2.Ch times between soccer and rugby players ($p > 0.05$), although significant difference was observed in sprint 15 m distance ($p \leq 0.01$) and 2.Ch ($p \leq 0.05$)

time between soccer and rugby players. In addition, soccer players recorded faster mean times in (FLT Z-Run Sprint) test than rugby players.

4.3 Strength characteristics

The following tables present the descriptive and significant difference statistics in absolute and relative one repetition maximum bench press (1RMbp) test for soccer and rugby players and only descriptive statistics in absolute and relative one repetition maximum back squat (1RMbs) test.

4.3.1 Bench press

Tab. 39 presents the descriptive and significant difference statistics in absolute and relative bench press test between soccer and rugby players.

Tab. 39: Bench press (mean \pm SD) and independent t-test (p) between soccer and rugby players

Variables	Sport	Mean \pm SD	Mean Difference	p
Absolute 1RMbp (kg)	Soccer	87.86 \pm 12.20	-12.86	0.02**
Absolute 1RMbp (kg)	Rugby	100.71 \pm 15.30		
Relative 1RMbp (kg ^{0.67})	Soccer	4.51 \pm 0.43	-0.40	0.06
Relative 1RMbp (kg ^{0.67})	Rugby	4.91 \pm 0.61		

** $p \leq 0.05$

There is significant difference in absolute (1RMbp) was found between soccer and rugby players ($p \leq 0.05$), although no significant difference observed in relative to body weight ($p > 0.05$). Rugby players had a higher mean in (1RMbp) than soccer players, whether absolute or relative to body weight.

4.3.2 Back squat

Tab. 40 presents the descriptive statistics in absolute and relative back squat test between soccer and rugby players.

Tab. 40: Back squat (mean \pm SD) for soccer and rugby players

Variables	Sport	Mean \pm SD	Minimum	Maximum
Absolute 1RMbs (kg)	Soccer	257.86 \pm 35.99	170	330
Absolute 1RMbs (kg)	Rugby	209.29 \pm 44.28	140	280
Relative 1RMbs (kg ^{0.67})	Soccer	13.30 \pm 1.85	9.46	16.10
Relative 1RMbs (kg ^{0.67})	Rugby	10.15 \pm 1.72	7.83	13.36

Descriptive statistics of back squat tests demonstrated that, soccer player had higher means than rugby players in absolute and relative to body weight, with respect to the different two testing devices.

4.4 Endurance characteristics

Tab. 40 presents the descriptive statistics in endurance characteristics for soccer players (FLT VO_{2max}) test and rugby players (3-km run) test.

Tab. 41: Endurance characteristics (mean \pm SD) for soccer and rugby players

Variables	Sport	Mean \pm SD	Minimum	Maximum
VO_{2max} (ml \cdot kg ⁻¹ \cdot min ⁻¹)	Soccer	52.16 \pm 3.05	45.69	55.42
VO_{2max} (ml \cdot kg ⁻¹ \cdot min ⁻¹)	Rugby	53.80 \pm 3.40	50.18	61.43
3-km run time (min)	Rugby	12.80 \pm 1.01	10.57	14.20

Descriptive statistics of endurance tests demonstrates that, rugby players had higher mean than soccer in VO_{2max} , with respect to the different two testing protocols in laboratory and field.

4.5 Correlation relationships between physical fitness variables for soccer and rugby players

Tab. 42 and 43 presents the correlation relationships between measurement variables (speed, strength and endurance) of physical fitness performance testing in current study for soccer and rugby players, respectively.

Correlations relationship in soccer

Correlations of test scores in physical fitness variables for soccer players are listed in Tab. 42. The results showed that, linear sprint 5 m was highly significant correlated with sprint 10 m ($r = 0.93$, $p < 0.01$), although observed moderately significant with sprint 30 m ($r = 0.64$, $p < 0.05$). In addition, linear sprint 10m was moderately significant correlated with 30 m sprint ($r = 0.61$, $p < 0.05$).

The results of (FLT Z-Run Sprint) showed that, non-linear sprint 8 m was highly significant correlated with 15 m ($r = 0.98$, $p < 0.01$) and 22 m ($r = 0.97$, $p < 0.01$) non-linear sprints. In addition, non-linear sprint 15m was also highly significant correlated with 22 m non-linear sprint ($r = 0.99$, $p < 0.01$).

Tab. 42: Correlation coefficients between physical fitness characteristics variables for soccer players

		5m (sec)	10m (sec)	30m (sec)	8m (sec)	15m (sec)	22m (sec)	1RMbp (kg)	1RMbs (kg)	VO _{2max} (ml·kg ⁻¹ ·min ⁻¹)
Linear sprint	5m (sec)	1								
Linear sprint	10m (sec)	0.93**	1							
Linear sprint	30m (sec)	0.64*	0.61*	1						
FLT Z-Run Sprint	8m (sec)	0.41	0.38	0.09	1					
FLT Z-Run Sprint	15m (sec)	0.36	0.35	0.10	0.98**	1				
FLT Z-Run Sprint	22m (sec)	0.33	0.31	0.09	0.97**	0.99**	1			
Strength test	1RMbp (kg)	0.00	0.02	-0.37	-0.30	-0.27	-0.24	1		
Strength test	1RMbs (kg)	-0.16	-0.21	-0.08	-0.21	-0.16	-0.13	0.25	1	
FLT VO _{2max} test	VO _{2max} (ml·kg ⁻¹ ·min ⁻¹)	-0.07	-0.14	-0.02	0.00	-0.10	-0.14	-0.34	-0.31	1

***p* < 0.01; **p* < 0.05
 VO_{2max} = maximum oxygen uptake; 1RMbp = one repetition maximum bench press; 1RMbs = one repetition maximum back squat

Tab. 43: Correlation coefficients between physical fitness characteristics variables for rugby players

		5m (sec)	10m (sec)	30m (sec)	8m (sec)	15m (sec)	22m (sec)	1RMbp (kg)	1RMbs (kg)	VO _{2max} (ml·kg ⁻¹ ·min ⁻¹)	Total time (min)
Linear sprint	5m (sec)	1									
Linear sprint	10m (sec)	0.98**	1								
Linear sprint	30m (sec)	0.82**	0.92**	1							
FLT Z-Run Sprint	8m (sec)	0.26	0.34	0.51	1						
FLT Z-Run Sprint	15m (sec)	0.20	0.34	0.56*	0.77**	1					
FLT Z-Run Sprint	22m (sec)	0.24	0.38	0.54*	0.60*	0.83**	1				
Strength test	1RMbp (kg)	-0.01	-0.03	-0.13	-0.50	-0.19	-0.26	1			
Strength test	1RMbs (kg)	-0.15	-0.21	-0.33	-0.66*	-0.34	-0.33	0.75**	1		
3-km run test	VO _{2max} (ml·kg ⁻¹ ·min ⁻¹)	-0.16	-0.16	-0.10	0.15	-0.20	-0.26	-0.60*	-0.77**	1	
3-km run test	Total time (min)	0.17	0.19	0.15	-0.11	0.28	0.32	0.56*	0.74**	-0.99**	1

***p* < 0.01; **p* < 0.05
 VO_{2max} = maximum oxygen uptake; 1RMbp = one repetition maximum bench press; 1RMbs = one repetition maximum back squat

There are no significant correlations observed between strength (1RMbp) and (1RMbs) tests score and also between sprint tests (linear and FLT Z-Run Sprint) with strength (1RMbp) and (1RMbs) tests score. The results showed same findings, which observed no significant correlations between endurance FLT VO_{2max} test with any other variables of speed and strength tests.

Correlations relationship in rugby

Correlations of test scores in physical fitness variables for rugby players are listed in Tab. 43 The results showed that, linear sprint 5 m was highly significant correlated with sprint 10 m ($r = 0.98$, $p < 0.01$) and sprint 30 m ($r = 0.82$, $p < 0.01$). In addition, linear sprint 10 m was also highly significant correlated with sprint 30 m ($r = 0.92$, $p < 0.01$).

The results of (FLT Z-Run Sprint) showed that, non-linear sprint 8 m was highly significant correlated with 15 m ($r = 0.77$, $p < 0.01$), although observed moderately significant with non-linear sprint 22 m ($r = 0.60$, $p < 0.05$). In addition, non-linear sprint 15 m was also highly significant correlated with 22 m non-linear sprint ($r = 0.83$, $p < 0.01$). Correlations results between linear and non-linear tests showed that, linear sprint 30m was moderately significant correlated with 15 m non-linear sprint ($r = 0.56$, $p < 0.05$) and 22 m non-linear sprint ($r = 0.54$, $p < 0.05$). In addition, non-linear sprint 8m was also moderately significant negative correlated with (1RMbs) strength test ($r = -0.66$, $p < 0.01$).

The results of strength tests showed that, (1RMbp) test score was highly significant correlated with (1RMbs) test score ($r = 0.75$, $p < 0.01$). In addition, (1RMbs) test score was observed highly significant correlated with estimated VO_{2max} of 3-km endurance run test ($r = -0.77$, $p < 0.01$) and the total time minutes of 3-km endurance run test ($r = 0.74$, $p < 0.01$), although (1RMbp) test score was observed moderately significant correlated with estimated VO_{2max} of 3-km endurance run test ($r = -0.60$, $p < 0.05$) and the total time minutes of 3-km endurance run test ($r = 0.56$, $p < 0.05$). There are no significant correlations observed between sprint tests (linear and FLT Z-Run Sprint) with estimated VO_{2max} and total time minutes of 3-km endurance run test.

5. Discussion

This chapter discusses the results of performance fitness testing between soccer and rugby players. As much as possible, the results of physical fitness characteristics in current study for soccer and rugby players will be compared with elite and professional players in previous studies from other countries, to establish a normative data for German soccer and rugby elite, sub-elite and professional players. In addition, this discussion provide useful feedback for coaches staff in both field team sports, which will help them when chooses talent players to participates in soccer and rugby union sports.

5.1 Anthropometric and age

In this part in discussion, the anthropometric profile (age, height, body weight and BMI) will be compared between soccer and rugby players in current study. In addition, the anthropometric characteristics and age profile results for soccer and rugby players in current study will be also compared with elite and professional players in previous studies from different countries.

The anthropometric results show no significant differences between soccer and rugby players in age, height and body weight, although significant differences was observed between both team players in (BMI). The average age of soccer and rugby players was 24 years. The results show soccer players taller (4 cm) 1.85 ± 0.07 m than rugby players 1.81 ± 0.05 m, while rugby players were heavier approximately (7 kg) 91.05 ± 12.16 kg than soccer players 83.86 ± 8.50 kg. The mean (BMI) of rugby players 27.77 ± 2.33 $\text{kg}\cdot\text{m}^{-2}$ showed higher than soccer players 24.50 ± 1.45 $\text{kg}\cdot\text{m}^{-2}$, with difference mean between them 3.27 $\text{kg}\cdot\text{m}^{-2}$.

5.1.1 Age

The average age of the soccer players in the current study was 24.57 ± 4.33 years. In previous studies, the mean age of soccer players at the elite and professional levels ranged between 21.9 ± 3.6 and 26.5 ± 4.0 years (Tab. 3, p. 38). The average age of soccer players in the current study was relatively similar to that of professional players in Turkey (Hazir, 2010) and to that of German

Bundesliga players (Reinhold, 2008), and was approximately 2.5 years greater than the age of Singaporean (Aziz, et al., 2000) and British (Strudwick, et al., 2002) players. The players in the current study were, on average, 1 year older than Croatian (Matkovic, et al., 2003), Serbian (Ostojic, 2003) and 3rd league German players (Hoppe, et al., 2012). The mean age of the soccer players in the current study was 1-2 years less than that of soccer players in other national leagues; it was also approximately 2.5 years lower than that of players in the 4 European leagues studied by (Bloomfield, et al., 2005), although German Bundesliga players participated in that study.

The average age 24.57 ± 4.33 years of soccer players in the current study was close to the normal average mean age of professional soccer players, who compete in high-level leagues, and it was in congruence both with the average ages of the members of other European first league teams (Reilly, 1990), and with the generally accepted claim, that the best performance in sporting games is achieved between the ages of 24 and 27 years. The mean age of the professional soccer players in the current study is also consistent with the results of (Reilly, 1996), who indicated that world class soccer players tend to have an average age of 26-27 years, with a standard deviation of approximately 2 years.

The average age of rugby players in the current study was 24 ± 3.94 years. In previous studies, the mean age of rugby players at the elite and professional levels was reported to be between 22.7 ± 3.2 and 27.61 ± 4.20 years, (Tab. 4, p. 44). The average age of rugby players in the current study was similar to that of New Zealand players (Argus, et al., 2011; Argus, et al., 2009), Australian players (Austin, et al., 2011), Argentinean players (Holway & Garavaglia, 2009) and Taiwanese players (Wu, et al., 2007), and approximately 1 year older than the New Zealand players studied by (Quarrie & Wilson, 2000), the Australian players studied by (Wheeler & Sayers, 2010) and elite German players (Kuhn, 2005). The rugby players in the current study were, on average 1-3 years younger than rugby players in other national leagues. The average age $24 \pm$

3.94 years of rugby players in the current study was close to the normal average mean for rugby players, who compete in high-level leagues.

(Tong & Mayes, 1997) reported a mean age for British professional rugby players ranging between 24.6 ± 2.7 and 25.6 ± 3.3 years. The mean age of professional rugby players in the current study was also consistent with the findings of (Nicholas, 1997), who reported the mean age of professional rugby forward players on 15 teams in United States, South Africa, Germany and England to be between 23 and 30.7 years and that of back players to be between 22.4 and 26 years.

The results of the current study showed no significant difference in age between soccer and rugby players, with a reported average age of ~ 24 years for players of both field team sports. The high degree of homogeneity in the ages of the players of these two field team sports provides an opportunity for a fruitful comparison in the physical fitness characteristics for soccer and rugby players. It may be that differences in the average ages of field team sports players explain some of the differences in the player's average physical fitness characteristics and skill abilities. Therefore, mean average age must be taken into consideration, when selecting sub-elite players to participate in the top-level soccer and rugby leagues, with respect to possible differences in physical fitness characteristics between elite and sub-elite players.

5.1.2 Height

The mean height of the soccer players in the current study was 1.85 ± 0.07 m. According to previous studies, the mean height of the soccer players in elite and professional levels ranged mean between 1.75 ± 0.06 and 1.83 ± 6.0 m (Tab. 3, p. 38).

The mean height of the soccer players in the current study was 2 cm greater than the mean heights of Serbian players (Ostojic, 2003) and German Bundesliga players (Bloomfield, et al., 2005; Reinhold, 2008). In addition, the soccer players in the current study were approximately 4-5 cm taller than elite

and professional players, whose mean heights ranged from 1.80 to 1.81 m, and observed taller 6-10 cm than players in range height mean from 1.75 to 1.79 m.

The mean height of the soccer players in the current study was greater than that of elite and professional soccer players from other countries, whose reported mean heights range from 1.75 to 1.84 m. This result suggests that German soccer players are, on average, taller than elite and professional players in European and other national soccer leagues and confirmed the results of (Bloomfield, et al., 2005), who reported that German Bundesliga players were significantly taller than European professional league players from England, Italy and Spain.

This difference in height between the soccer players in the current study and that of players in the national leagues of other countries is unlikely to confer any advantage in soccer because height is primarily important when selecting youth players or assigning player positions in soccer. In this respect, it may be that soccer players in Germany were found to be taller than other national league players in the current study and in the study of (Bloomfield, et al., 2005), because the top league players in Spain and Italy include many more players from South America and, on average, these players are shorter than German players. In any case, body height is not considered to be an important success factor for professional players in soccer. Naturally, other factors for success include a player's physical fitness profile, tactical awareness and teamwork abilities.

These findings are consistent with previous studies of soccer teams (Matkovic, et al., 2003) that suggest it is highly probable that height itself does not guarantee success in soccer. Nevertheless, it is also likely that, for young players, body height has an important role in the selection of players for particular positions before these players enter the senior competition level and undergo the adaptation of training.

The mean height of the rugby players in the current study was 1.81 ± 0.05 m. According to previous studies, the mean height of rugby players at the elite and

professional levels ranged between 1.77 ± 5.45 and 1.88 ± 7.1 m (Tab. 4, p. 44). The mean height of rugby players in current study showed relatively similar to Croatian-Slovenian (Babic, et al., 2001) players, elite players over 20 years (Austin, et al., 2011; Olds, 2001), with 1 cm mean difference between them. In addition, the rugby players in the current study were approximately 2-5 cm taller than elite and professional players, whose mean heights were between 1.76 and 1.79 m and 1.83 and 1.87 m, respectively, and 3 cm shorter than elite German rugby players.

The mean height of the rugby players in the current study was similar to the mean height of all rugby players in other national high-level leagues, although it was 3 cm less than the mean height of elite German rugby players. The differences in the mean heights of rugby players in the current study and those in other national leagues, whether large or small, may be related to geographical distribution within these countries.

As with soccer, body height is not an important factor in the success of rugby players. Previous studies have indicated that body weight is more important than body height for rugby players. Height may represent an appropriate factor on the basis of which to compare player positions and to identify the roles of forward and back rugby players. The previous results of (Norton & Olds, 2001; Olds, 2001) indicated that, body weight of players is an important success factor in rugby union competitions and documented a more rapid increase in the body weight of players over the past 20 years than in body height, which was observed to have increased at the same rate as the height of individuals involved in other sports.

The current study found no significant difference in body height between soccer and rugby players, although soccer players were, on average, 4 cm taller than rugby players. The mean difference in height between players of these two field team sports and players from other European teams may be explained by the natural morphology of German soccer players, who have been observed to be the tallest compared with players in other national European soccer leagues.

A comparison of the results in previous studies of the mean heights in elite and professional soccer and rugby players, which are presented in Tab. 3 and 4 (p, 38 and 44), shows that the Bundesliga soccer players studied by (Bloomfield, et al., 2005; Reinhold, 2008) were also an average of 4 cm taller than the Argentinean rugby players studied by (Holway & Garavaglia, 2009) when the results were normalized by players' age.

The findings concerning the mean heights of the soccer and rugby players in the current study confirms the results of a study by (Norton & Olds, 2001), which indicated that soccer and rugby players were, on average, similar in height to the general population, with similar variability as expressed by standard deviation values. Thus, height is not an essential factor for success in soccer or rugby union sports, although it may contribute to determining playing position in both field team sports.

In fact, taller players tended to have advantages in certain positions such as goalkeeper or forward in soccer and as forward, especially lock players, in rugby. These ideas are consistent with those of (Reilly, et al., 2000) who suggested that, there were likely to be anthropometric predispositions for different positional roles, with taller players seeming the most suitable for central defensive positions and for the target players among the strikers or forwards.

(Duthie, et al., 2003) suggested that there is a clear difference in height between forward and back rugby players and that this is particularly evident for the locks position; although players at this position display vertical jump performance that is similar to that of other forwards, their greater height allows them to achieve a superior absolute jumping height in the line-out. These results also support the idea that height might be a factor in determining player position in both soccer and rugby.

5.1.3 Body weight

The mean body weight of the soccer professional players in the current study was 83.86 ± 8.5 kg. According to previous studies, the mean body weight of soccer players in elite and professional levels reported range mean between

65.5 ± 6.1 to 78.6 ± 7.1 kg, (Tab. 3, p. 38). The mean body weight of the soccer players in the as 5-10 kg greater than that of soccer players in other national leagues and more than 10 kg greater than that of Singaporean players. In addition, the soccer players in the current study were approximately 5 kg heavier than German Bundesliga players (Bloomfield, et al., 2005; Reinhold, 2008).

Although the mean body weight of the soccer players in this study was greater than that of players in other national leagues, it was within the range of mean body weight of Croatian first-league players in the study of (Matkovic, et al., 2003), who reported means ranging from 63.5 to 93.0 kg. The higher mean weight of soccer players in the current study may be due to the time of fitness testing time or to the fact that fewer soccer players participated in the current study.

The difference in average body weight may be explained by the morphological characteristics of the German soccer players in the current study. This explanation is consistent with that of (Bloomfield, et al., 2005), who reported that German soccer players were heavier than soccer players in European leagues from England, Italy and Spain and attributed this difference to the fact that the playing style in the Bundesliga is based on power and athleticism.

The mean body weight of rugby union professional players in the current study was 91.05 ± 12.16 kg. In previous studies, the mean body weights of rugby players at the elite and professional levels ranged between 85.5 ± 9.61 and 107.1 ± 10.1 kg (Tab. 4, p. 44). The mean body weight of rugby players in the current study was relatively similar to that of USA players (Carlson, et al., 1994). The rugby players in the current study were approximately 6-13 kg lighter than New Zealand players (Argus, et al., 2009; Crewther, et al., 2011; Quarrie & Hopkins, 2007), 7-10 kg lighter than Australian players (Austin, et al., 2011), 7 kg lighter than British players (Gamble, 2004) and 8 kg lighter than Italian players (Pogliaghi, et al., 2011).

In contrast, the rugby players in the current study were 2-6 kg heavier than Croatian-Slovenian, Taiwan and Argentinean players, who ranged in weight

from 85.50 to 89.5 kg, and 3 kg lighter than elite German rugby players (Kuhn, 2005). In addition, rugby players in current study were lighter than New Zealand, Australian, British and Italian players. This observation may be due to differences in the level of competition between Germany and other countries and the relative world rankings of various national teams. The international rugby union board ranked these countries at a higher level than Germany, while Croatia, Taiwan and Argentina are ranked lower than Germany in the world ranking.

These results are consistent with those of (Gabbett, 2002a), who reported a significant difference in body mass between first-league players 93 ± 10 kg and second-league players 86 ± 10 kg in body mass and recorded 7 kg mean difference between them. Additionally, (Nicholas & Baker, 1995) observed that forward rugby players in the first league 97.3 ± 1.9 were 6 kg heavier than forward players in the second league 91 ± 1.6 kg. Along the same lines (Sedeaud, et al., 2012) indicated that the average body mass of rugby players in World Cups has increased over the past 20 years and suggested that the forward players in winning, finalist, semifinalist and quarter finalist teams were significantly heavier than the forward players on other teams.

This finding indicates that, on average, rugby players who participate in top-level competitions are heavier than players who participate in lower-level competitions. Therefore, the difference in body mass between German rugby players and players in other national leagues may be related to the level of rugby union matches in which these teams participate. The results indicates that body weight is an important factor in rugby because the natures of this contact sport requires players who can tackle, breaking tackles and scrummaging, and, for these skills, it is preferable to possess body weight as lean body mass. This finding leads to the conclusion that body weight is an important factor for success in rugby union games. This should be taken into consideration when selecting sub-elite rugby players and by rugby coaches when planning their players' seasonal training.

With respect to comparison of the body weights of soccer and rugby players, the results of the current study showed no significant difference in body weight between soccer and rugby players, although the body weight of rugby players was 7 kg greater than that of soccer players. This mean difference in the weights of players in these two field team sports may be caused by the natural morphology of rugby players, who have been observed to be heavier than players in national soccer leagues. The results of previous studies comparing the body weights of elite and professional soccer and rugby players, in Tab 3 and 4 (p, 38 and 44), show that rugby players are, on average, approximately 10 kg heavier than soccer players of the same age. This finding confirms the results of the current study, which shows that rugby players are generally heavier than soccer players.

Previous studies that compared soccer and rugby players in the same age range 24 years, as the present study showed that German rugby players 88.2 ± 13.7 kg (Kuhn, 2005) were 8-10 kg heavier than German Bundesliga soccer players 78.6 ± 7.1 kg in the study of (Reinhold, 2008); 80.60 ± 6.38 kg in the study of (Freiwald & Baumgart, 2012). In any case, no significant difference in body weight between soccer and rugby team players was found in the current study. This finding may be explained by the natural morphology of soccer players in Germany, who tend to be taller and heavier than players in other national leagues. The mean body weight of rugby players in the current study was 7 kg greater than that of soccer players. This result may be explained by the nature of rugby union sport, in which body weight has been reported to be an important factor for success. Therefore, it is not surprising that rugby players were found to be heavier than soccer players in the current study.

These explanations confirm the results of previous studies. The Bledisloe cup study (1972 to 2004) by (Sedeaud, et al., 2012) showed that body weights of both forward and back players increased significantly 7.1% and 12.3%, over the time period studied. In addition, (Quarrie & Hopkins, 2007) indicated that the most successful rugby teams had greater average body mass than other teams. Greater body mass appears to confer an advantage in the contact phases of the sport, because of the great momentum that heavier players are able to generate.

5.1.4 Body mass index (BMI)

The mean (BMI) of the soccer players in the current study was $24.50 \pm 1.45 \text{ kg}\cdot\text{m}^{-2}$. According to previous studies, the mean (BMI) of soccer players at elite and professional levels reported range mean between 21.39 and $24.87 \text{ kg}\cdot\text{m}^{-2}$, (Tab. 3, p. 38). The mean (BMI) of the soccer players in the current study was similar to that of South American (Rienzi, et al., 2000), Spanish (Casajus, 2001), French (Cometti, et al., 2001), Norwegian (Wisloff, et al., 2004), Greek (Kalapotharakos, et al., 2006), German (Freiwald & Baumgart, 2012) and Turkish players (Hazir, 2010). However, the mean (BMI) of the soccer players in this study was $1\text{-}3 \text{ kg}\cdot\text{m}^{-2}$ greater than that of soccer players in other national leagues and approximately $1 \text{ kg}\cdot\text{m}^{-2}$ greater than that of German soccer players in the Bundesliga.

The mean difference in (BMI) between the soccer players in the current study and those in previous studies of soccer players in other national leagues was not large; the mean BMI value, $24.18 \pm 1.18 \text{ kg}\cdot\text{m}^{-2}$, was similar to that of soccer team participants in the German Bundesliga (Freiwald & Baumgart, 2012). The small difference in mean (BMI) $1 \text{ kg}\cdot\text{m}^{-2}$ between the soccer players in the current study and the Bundesliga players in the previous study of (Reinhold, 2008) may be related to the time of testing, although the participants were similar in age, with an average age of 24 years. In addition, the increased BMI of the soccer players in the current study was not more than $1\text{-}2 \text{ kg}\cdot\text{m}^{-2}$ greater than the mean BMI of participants in three European soccer leagues from England, Italy and Spain (Bloomfield, et al., 2005), although the players in these leagues were, on average, 2 years older than soccer players in current study.

The results do not suggest that the average mean age of the soccer players is related to their (BMI). The performance testing time may explain the small observed difference in (BMI) between the soccer players in the current study and soccer players from other national leagues. This finding is consistent with the results of a previous study by (Ostojic, 2003) in which it was reported that body fat percentage decreased by $9.6 \pm 2.5\%$ during competitive periods and increased by $12.6 \pm 3.3\%$ during break season periods.

The mean (BMI) of the rugby players in the current study was $27.77 \pm 2.33 \text{ kg}\cdot\text{m}^{-2}$. In previous studies, the reported mean (BMI) of rugby players at the elite and professional levels ranged between 26.05 and $30.49 \text{ kg}\cdot\text{m}^{-2}$, (Tab. 4, p, 44). The mean (BMI) of rugby players in the current study was similar to that of USA players (Carlson, et al., 1994), Croatian-Slovenian players (Babic, et al., 2001), Taiwanese players (Wu, et al., 2007) and Argentinean players (Holway & Garavaglia, 2009), but it was $1.5 \text{ kg}\cdot\text{m}^{-2}$ less than that of German rugby players (Kuhn, 2005).

This observation may be due to the similarity in world rank of rugby players in these countries, which are ranked at a lower level than rugby players from other countries, who had mean (BMI) between 28 and $30 \text{ kg}\cdot\text{m}^{-2}$. This finding is not surprising, because these countries were also observed to have players with mean body weights less than those of players from other countries. The findings also confirm that players who play at the top level need to have better body size than players at lower competitive levels. In addition, the results of the current study are consistent with those of a previous study by (Sedeaud, et al., 2012), who reported that mean body weight and (BMI) increased in each rugby union World Cup by 1.34 kg and $0.33 \text{ kg}\cdot\text{m}^{-2}$, respectively, for forward players and by 1.46 kg and $0.30 \text{ kg}\cdot\text{m}^{-2}$, respectively, for back players.

In the current study, a significant difference in BMI ($p \leq 0.01$) was found between soccer and rugby players. The mean BMI of rugby and soccer players in the current study were $27.77 \pm 2.33 \text{ kg}\cdot\text{m}^{-2}$ and $24.50 \pm 2.33 \text{ kg}\cdot\text{m}^{-2}$, respectively. The comparable results between soccer and rugby players in mean (BMI) found in previous studies and shown in Tab. 3 and 4 (p. 38 and 44) supports the results obtained in the current study.

Comparable results have been obtained for soccer and rugby players of the same age (24 years) in previous studies. In these studies, Argentinean rugby players were reported to have a mean BMI of $27.93 \text{ kg}\cdot\text{m}^{-2}$, New Zealand players a mean BMI of $30.39 \text{ kg}\cdot\text{m}^{-2}$ and Taiwanese players a mean BMI of $27.29 \text{ kg}\cdot\text{m}^{-2}$; these values are higher than the mean BMI of Turkish soccer players $23.32 \text{ kg}\cdot\text{m}^{-2}$ (Hazir, 2010), German players in Bundesliga $23.47 \text{ kg}\cdot\text{m}^{-2}$

(Reinhold, 2008) and other team participants in the Bundesliga 24.18 kg·m⁻² (Freiwald & Baumgart, 2012).

The observed difference in BMI between rugby and soccer players could be explained by increases in training load coupled with nutritional follow-up. In addition, in recent years rugby has become a sport in which heavy players have become increasingly important. Therefore, maximal build and superior body size are important factors for international rugby players. This explanation is consistent with (Olds, 2001), who reported that, rugby players have increased in body size in the twentieth century and indicated that increases in the mass of male rugby players were more rapid than increases in the mass of males in the general population. In addition, the comparison between football code sports supports the findings of the current study; (Brick & O'Donoghue, 2005; Kuhn, 2005) reported that rugby players showed significantly higher BMI than soccer players.

The results of these studies indicate that selection to higher-level teams in contact sports such as rugby union may be partially based on player size. The benefits of a lower center of gravity and increased muscularity may be significantly greater to rugby players than to soccer players because the latter sport places less emphasis on the force required in contact between players. These factors may result in a higher (BMI) in rugby than soccer players.

Based on the anthropometric results obtained in this study, this study concludes that the mean age, height, and (BMI) of the participants in this study do not significantly deviate from that of the average population of soccer and rugby players of the same age in Germany. However, for both field team sports, body weight values were greater than those reported for other German players in previous studies, and this was naturally to be expected taking into account the participation of the players in physical activity and the time of fitness testing. In any case, the differences in anthropometric profile value means between the current study and previous studies may be explained by the strategies used in the talent identification process in these countries and the levels of various countries' system leagues in their federations.

5.2 Speed

In this part of the discussion, performance in the linear (5 m, 10 m and 30 m) sprint and non-linear (FLT Z-Run Sprint) of the soccer and rugby players in the current study will be compared. The mean score times results of the soccer and rugby players in current study will be also compared with those of elite and professional players in previous studies from different countries.

5.2.1 Linear sprint (5 m, 10 m and 30 m)

The mean times of the soccer players in the current study over 5 m, 10 m, and 30 m were 1.11 ± 0.04 sec, 1.85 ± 0.05 sec and 4.24 ± 0.17 sec, respectively. In previous studies, the mean times of the soccer players in elite and professional levels ranged scores over 5 m, 10 m, and 30 m between 0.96 ± 0.04 and 1.46 ± 0.07 sec, 1.66 ± 0.05 and 2.27 ± 0.04 sec and 3.97 ± 0.12 and 4.28 ± 0.12 sec, respectively, (Tab. 9, p. 60). The mean times of the soccer players in the current study over all distances in the linear sprint test were observed to be slower than the times of German, Japanese and Australian players, although they were faster than Croatian and Belgian players in 5 m and 10 m sprints. In addition, they were slower than those of soccer players of other nation leagues in the 30-m sprint, although faster than the Turkish players.

Many factors might explain this difference between the sprint performance of the soccer players in the current study and that of other national league players; these factors include body fat percentage, match performance activities, measurement methods and time of fitness testing. The fact that the soccer players in the current study were slower than the German elite and professional players may be due to the mean body mass of the soccer players in the current study. The soccer players in the current study were heavier than DFB elite soccer players, who showed faster sprint performance than the soccer players in the current study, by approximately 6 kg. This explanation is consistent with the results of a previous study by (Ostojic, 2003), who reported that the body fat content of elite professional soccer players decreased significantly during the conditioning and competitive periods and increased during the off-season and

that changes in sprint times were strongly correlated with changes in percentage of body fat.

In addition, soccer players in the current study showed faster in linear sprint performance than Croatian and Belgian players. This difference may be related to the level performance of these national soccer teams. The German team ranked at the third level in the FIFA world ranking table, while the Croatian and Belgian teams were ranked at a lower level with respect to the participating clubs and the testing time.

The soccer players in the current study showed slower in linear sprint performance than the players on the DFB elite team. This result may be also be related to differences in match performance activities such as sprinting and total numbers of runs in soccer. This explanation is consistent with the previous study of (Verheijen, 2000), in which it was reported that Netherlands defenders, midfielders and attackers in professional soccer leagues recorded more total runs in soccer games than top-class amateurs. For example, midfielders in professional leagues recorded a total of 1570 runs, while midfielder players in top class amateur leagues recorded 1345 runs.

Based on the general comparison of soccer players in the current study and those in previous studies, it could be said that the soccer players in the current study were generally slower at running the 30 m linear sprint distance than soccer players in other national leagues. Similar conclusions were drawn by (Geese, 1990), who suggested that soccer players who record times between 4.15 and 4.24 sec in the 30 m linear sprint were generally classified as poor in sprint performance and (Coen, et al., 1998) who profiled strong sprint performance for German national soccer players in the 30 m linear sprint as < 4 sec.

The mean 5 m, 10 m, and 30 m sprint times of the rugby players in the current study were 1.22 ± 0.10 sec, 1.99 ± 0.12 sec and 4.58 ± 0.19 sec, respectively. In previous studies, the range mean 5 m sprint times of rugby players at the elite and professional levels fell between 1.14 ± 0.06 and 1.20 ± 0.11 sec, although

relatively few studies investigated players' performance in the linear 5 m sprint. For the same group of players, 10 m sprint times ranged between 1.69 ± 0.10 and 2.19 ± 0.11 sec, and 30 m times were between 4.17 ± 0.14 and 4.81 ± 0.16 sec. These data are presented in Tab. 14 (p, 69).

The mean time of the rugby players in the current study in the linear 5 m sprint was slower than that of Australian players in the first and second leagues. For the linear 10 m sprint, the mean time of the rugby players in the current study was slower than that of Australian players (Jenkins & Reaburn, 2000), American players (Walsh, et al., 2007), Australian first league players (Gabbett, et al., 2008), British players (Crewther, et al., 2011) and Irish professional players (Green, et al., 2011), although it was faster than that of Australian and Irish professional club players, who recorded mean scores > 2 sec (Gabbett, 2002a; Green, et al., 2011). In addition, their score in the linear 30 m sprint was faster than that of Australian first and second grade players and slower than that of Irish professional academy players; in fact, it was the same as that of the Irish professional club players.

The rugby players in the current study were faster than the Australian players in the 10 m and 30 m sprints. This may be explained by differences in years of training or level of competition. The Australian players in this study are semi-professional, while the German rugby players are part of an international team. The difference in training and experience between the two teams may explain their differences in linear sprint performance. This finding is consistent with the results of a study by (Gabbett, 2002a), who reported that rugby players in the first league, who showed significantly more (3 years more) playing experience than second-league players, were significantly faster than the second-league players in linear 10 m and 30 m sprints 2.15 ± 0.15 and 2.19 ± 0.11 sec and linear 30 m sprint 4.81 ± 0.16 and 4.80 ± 0.17 sec, respectively.

The previous findings by (Gabbett, 2002a) also explain why rugby players in the current study were slower in 10 m and 30 m linear sprints than Australian professional players (Gabbett, et al., 2008) and British professional players

(Crewther, et al., 2011). Australian players are at the second rank worldwide, and they are ranked higher in rugby union around the world. In addition, during matches, players who compete at a higher competition level, such as the New Zealand and Australian players, perform more total activities, such as sprints, than players who compete in lower performance leagues, such as the rugby players in Germany. However, the few studies available do not fully explain the observed differences in performance between German rugby players, whose performance during rugby games has been investigated by time-motion analysis, and other players.

The results of the current study demonstrate a significant difference ($p \leq 0.01$) in the performance of soccer and rugby players in linear 5 m, 10 m and 30 m sprint tests. The mean times of soccer players in these sprints were 1.11, 1.85 and 4.24 sec and rugby players 1.22, 1.99 and 4.58 sec, respectively. To my knowledge, no studies have investigated differences in performance between soccer and rugby players in linear sprints. Comparable results from previous studies of the performance of elite and professional soccer and rugby players in 5 m, 10 m and 30 m linear sprints are presented in Tab. 9 and 14 (p, 60 and 69); they also show that soccer players are faster than rugby players, confirming the findings of the current study.

The results in the table show that German soccer players (Freiwald & Baumgart, 2012; Meyer, et al., 2000; Reinhold, 2008) and Australian soccer players are faster than Australian rugby players (Gabbett, 2002a; Gabbett, et al., 2008) over all linear sprint distances. In the context of comparison between football code sports, (McIntyre, 2005) reported that soccer players 2.48 ± 0.10 sec were faster than Gaelic football players 2.53 ± 0.10 sec, when tested in a 15 m sprint. This finding is also consistent with the results of the current study, which showed soccer players to be faster than rugby players in a comparison of football code contact sports. The results of (Strudwick, et al., 2002) also showed that soccer players (1.75 ± 0.08 and 4.28 ± 0.12 sec) were faster than Gaelic football players (1.89 ± 0.17 and 4.60 ± 0.30 sec) over 10 m and 30 m.

The results of the current study are also consistent with those of (McIntyre, 2005; Strudwick, et al., 2002) when soccer and rugby players are compared. In the current study, soccer players outperformed rugby players in explosive acceleration over 5 and 10 m. This result is consistent with the results of (Carling, et al., 2009), who reported that speed and acceleration over short distances are especially important for all soccer players, while they are important for backs in rugby only when attacking and cover defending.

The observed differences in sprint performance between soccer and rugby players could be explained by the nature of sprint performance in rugby union game. During a game, rugby players sprint with the ball in their hands; this may be a negative factor that negatively influences sprint performance, whether these players accelerate over a 10 m distance or run a maximum distance of 30 m. However, soccer players can accelerate and run with free movement. In this light, it is interesting that the rugby players in the current study were significantly slower than soccer players even though both soccer and rugby players were measured in linear sprint tests without ball.

The difference in sprint performance between soccer and rugby players in the current study may also be explained by the very significant difference between these players in (BMI), which represents an indirect measurement of body fat. Rugby players had a higher mean (BMI) than soccer players; this may have influenced the sprint times of the two groups. Comparing the two field team sports, rugby union matches are 80 min in duration, while soccer games last for 90 min. Therefore, the energy demands on rugby players may be not as great as those on soccer players, for whom match play is 90 min in duration. Furthermore, soccer player's play full time and with more intensity, and the greater frequency of competition may be responsible for the difference in stored body fat.

(Duthie, et al., 2003) offered a similar explanation and reported that lower body fat in back rugby players reflects the higher speed requirements of those players, similar to other sports such as field hockey, soccer and sprinting. In

addition, (Strudwick, et al., 2002) observed that soccer players are lighter than Gaelic football players and reported a difference in body fat between the two groups. In addition to these findings, differences in the total number of training hours may explain the observed difference in body fat between the soccer and rugby players in the current study. While soccer players trained 6 days per week and participated in 1-2 training sessions per day, rugby players trained only 4 days per week with one training session per day.

The differences in linear sprint performance between soccer and rugby players may also be related to the total distance covered and the percentage of time spent in different activities, such as sprinting, by these players during match play. Rugby can be characterized as a typical 'stop-and-go' game, whereas soccer is a relatively continuous game and includes more passes, runs with the ball, dribbles and crosses. These characteristics suggest that play proceeds at a significantly faster tempo in soccer games and that it involves more sprinting activities, reflecting the difference between these two field team sports in required speed performance. These explanations are borne out by previous studies of elite and professional soccer and rugby players, although no prior studies have investigated differences in match performance activities between German soccer and rugby players.

This explanation, which attributes the difference in linear sprint performance to differences between soccer and rugby players in total sprinting time during games, is consistent with the results of previous studies that have investigated the match performance activities for these two field team sports. Based on comparable results of previous studies of elite and professional soccer (Bradley, et al., 2009) and rugby (Cunniffe, et al., 2009) players in match performance activities, soccer players covered 1253 meters in sprinting activity during an average soccer game, while rugby players covered only 837 meters in sprinting activity during an average rugby game, a difference of 416 meters. These studies also showed that back players 524 m covered more distance (524 m) in sprinting activities than forward players (313 m) in rugby union games. In soccer

games, midfield and attacking players covered 814 m in sprinting activity, compared to defensive players, who covered 439 m.

The natures of these two field team sports also play an important role in explaining this difference in sprint performance between soccer and rugby players. In matches, rugby players covered 5.2 to 7.2 km and spent 85% of the match in low-intensity activities (standing, walking, jogging and utility movements) and 15% in high-intensity activities (cruising, sprinting, scrummaging, rucking, mauling, and tackling) (Deutsch, et al., 2007; Duthie, et al., 2003). These findings support the concept that rugby involves short bouts of high-intensity activity interspersed with long periods of low-intensity activity. Soccer match analysis, on the other hand, revealed that soccer players generally cover 9.5 to 12 km distance during a 90-min game and that approximately 40% of this distance consists of high-intensity running and 1-11% of sprinting (Bangsbo, et al., 1991; Mohr, et al., 2003).

These findings confirm that static and dynamic movements such as rucking, mauling, tackling are important components for forward rugby players and that backs spend approximately two to three times more sprinting than forwards, irrespective of playing conditions. However, (Bangsbo, et al., 1991; Mohr, et al., 2003) reported that, in soccer games, forwards and fullbacks spent 20-40% more time sprinting than midfielders and center backs. This information regarding match activities performance of soccer and rugby players will be useful in selecting young players to participate in both sports and also in guiding them to the most appropriate playing positions in soccer and rugby unions.

5.2.2 Non-linear (FLT Z-Run) sprint

In this part of the speed discussion, the results of the current study will be compared with those of previous studies with regard to the recorded time scores of soccer players in the non-linear (FLT Z-Run Sprint) test. It must be taken into consideration that few studies have established normative data for soccer players in the (FLT Z-Run Sprint) test; also, no previous studies have established data for rugby players. The current study will also compare soccer

and rugby players' performance on the non-linear sprint tests used in previous studies for elite and professional soccer and rugby players.

The mean times of professional soccer players in the current study over 8 m, 15 m, and 22 m in non-linear (FLT Z-Run Sprint) test were 1.61 ± 0.25 sec, 3.36 ± 0.50 sec and 5.43 ± 0.80 sec, respectively. In addition, the mean score times in 1.Ch and 2.Ch directions were 0.90 ± 0.17 sec and 0.86 ± 0.14 sec, respectively. In previous studies in (Tab. 11, p. 61), soccer players in the current study over all parameter distances of (FLT Z-Run Sprint) test recorded approximately score times similar to soccer players who compete in the Bundesliga (Freiwald & Baumgart, 2012) and observed faster than soccer players in Regionalliga.

The differences in observed performance between the soccer players in the current study and Regionalliga players may be explained by the wide difference in the physical fitness conditioning training of the two groups. In addition, the soccer players in the current study sprinted linear 30 m faster than Regionalliga players, and this performance ability is related to the ability of players in non-linear sprint tests. Soccer players who are fast over linear sprints are also the fastest over non-linear sprints. This observation is consistent with that of (Reinhold, 2008), who observed a highly significant ($p < 0.0001$) difference in 30- m linear sprint times between soccer Bundesliga players 4.13 ± 0.12 sec and Regionalliga players 4.29 ± 0.15 sec. In addition, (Freiwald & Baumgart, 2012) reported moderate correlation between sprint in straight line 30 m and sprint in non-linear line 22 m, ($r = 0.60$, $p < 0.05$).

The difference between the two soccer leagues may also be related to differences between them in total covered distance in the game. Soccer players in Bundesliga may cover total distances that involve more multidirectional turns than Regionalliga players. This explanation is consistent with the work of (Verheijen, 2000), who reported that soccer players in professional leagues in the Netherlands recorded a greater total number of sideways runs during games than second top-level amateurs. For example, professional league players

recorded 441 sideways runs, while second-class amateur players recorded 280 sideways runs, a difference of 161 total sideways runs. This finding indicates that good starting and rapid acceleration are vital for soccer players in achieving good sprint performance in non-linear runs and that coaching staff must include both linear and non-linear sprinting in training sessions. These results could also be used as a prediction factor for soccer player identification.

The mean sprint times of the rugby players in the current study over 8 m, 15 m, and 22 m in the non-linear (FLT Z-Run Sprint) test were 1.67 ± 0.09 sec, 3.82 ± 0.14 sec and 5.86 ± 0.18 sec, respectively. The mean times in the 1.Ch and 2.Ch directions were 1.02 ± 0.10 sec and 0.88 ± 0.11 sec, respectively. It must be taken into consideration that the (FLT Z-Run Sprint) test has not previously been used in studies of rugby players and that there is therefore no normative data available on the time scores of rugby players in the (FLT Z-Run Sprint) test. Therefore, the discussion in this section will compare German rugby players with rugby players from other countries according to the non-linear (L Run) sprint test, which was used in previous rugby studies.

Previous studies, some data from which are shown in (Tab. 16, p. 70), used tests that investigated the non-linear sprinting ability of rugby players. The mean sprint time of rugby players in the current study in the (L Run) non-linear sprint test was 6.56 ± 0.31 sec, slower than that of first-league 6.36 ± 0.53 sec and second-league 6.49 ± 0.40 sec Australian players. The difference in performance between German players and Australian players in the non-linear sprint test may be caused by differences between them in match performance activities or in the number of turns in the total distance covered in rugby games.

Australian rugby players are among the best rugby players in the world. This may reflect their superior physical fitness conditioning compared to German rugby players, who are ranked thirty-first in the world ranking system for rugby players. Although this difference can explain our finding, there may be additional reasons why Australian rugby players perform better in non-linear sprinting movement than German rugby players. Naturally, physical fitness trainers in

countries such as New Zealand and Australia are professional trainers and are likely to have more experience than rugby trainers in Germany.

The (L Run) test is a good non-linear test that can differentiate professional rugby players in different leagues and classify them yielding a high interclass correlation coefficient ($r = 0.95$, $p < 0.01$). One reason in particular may explain the observed difference between German and Australian rugby players in non-linear sprint (L Run) performance; this is that non-linear sprint performance is better in Australian rugby players than in German rugby players because of the different levels of competition experienced by each group. This explanation is consistent with the results of the previous study of (Gabbett, et al., 2008), who reported that professional rugby players in the first league were faster 6.36 ± 0.53 sec than professional rugby players in the second league 6.49 ± 0.40 sec, when the non-linear (L Run) sprint test was used to measure differences between the players in the two leagues.

The results of the current study demonstrated a significant difference between soccer and rugby players in 15 m ($p \leq 0.01$) and 1.Ch turn ($p \leq 0.05$) performance in the non-linear sprint test. The mean 15 m and 1.Ch turn parameters were (3.36 ± 0.50 and 0.90 ± 0.17 sec) and rugby players (3.82 ± 0.14 and 1.02 ± 0.10 sec), respectively. However, no significant differences between soccer and rugby players were found in the 8 m, 22 m or 2.Ch turn parameters of the (FLT Z-Run Sprint) non-linear test. In previous studies in Tab 11 and 16 (p, 61 and 70), which show the non-linear (Illinois agility run) test scores of elite and professional soccer and rugby players from previous studies.

The mean (Illinois agility run) test scores for rugby players in previous studies were slower than those of soccer players. These results are consistent with the results of previous studies that compared field team sports players using non-linear tests. (Kuhn, 2005) investigated field team sports using an agility test that required players to traverse an obstacle course in which jumping, rolling and bending movements, as well as various changes in direction, were demanded. Rugby players recorded the slowest time 8.0 ± 0.6 sec, compared with American

football players 7.8 ± 0.9 sec and soccer players 7.5 ± 0.7 sec, although no significant difference showed between the three field team sports.

The 8 m parameter in the non-linear (FLT Z-Run Sprint) test could be classified as a factor that predicts the acceleration ability of soccer and rugby players when running and changing direction. In this study, although soccer players had faster score times than rugby players over this distance, the difference was not significant. This result may be related to the greater extent of lower body power training in rugby players. Rugby players undergo more extensive lower body power training than soccer players because this factor is related to basic skills in rugby such as scrumming and mauling, in which players need more power during contact with other team players. The superior lower body power training of rugby players may have given them a good start and rapid acceleration over the 8 m distance, although soccer players had a better mean time over this distance. This non-significant result may also be explained by the lower mean BMI of the soccer players.

In the current study, the results for the 15 m and 1.Ch parameters were significantly different for soccer and rugby players; soccer players were faster than rugby players on both, although the results for the 8 m, 22 m and 2.Ch turn runs of the non-linear (FLT Z-Run Sprint) test were not significantly different for soccer and rugby players. However, soccer players had higher mean score times than rugby players for these parameters.

The non-significant difference in the scores of soccer and rugby players on the 8 m and 22 m parameters of the non-linear (FLT Z-Run Sprint) test may be explained by the nature of running in rugby union games. Rugby players tend to run with a closed upper-body posture and a notable forward lean; running lower and in a more compact posture reduces exposure to tackles while also enhancing body position and facilitating deceleration and turning to make tackles or hit rucks. This skill in rugby reflects high reactive agility; thus, it could be that higher reactive agility in rugby game performance was significantly related to these players' high ability when performing changes of direction.

The significant differences in the scores achieved by soccer and rugby players on the 15 m and 1.Ch turn parameters of the non-linear (FLT Z-Run Sprint) test might be explained by the nature of running in soccer games. Compared to rugby players, soccer players run and dribble the ball diagonally in more directions. This skill may also explain why soccer players sprinted faster than rugby players when running with the ball. Rugby players, who run with the ball under one hand, may change their lateral direction more often than soccer players, who more often run diagonally.

This explanation is consistent with the results of an earlier soccer study by (Bloomfield, et al., 2007), who found that professional soccer players spent a greater percentage of time running in the forward diagonal right than in the forward diagonal left direction and that the number of 90° to 180° turns is relatively evenly distributed among players, with all positions performing approximately the same number of turns between 90° and 100° in match play. Therefore, it appears likely that soccer players spend less time in 1.Ch maneuvers to the left side than they do in 2.Ch to maneuvers to the right side. This may explain the observation of the current study that soccer players are faster than rugby players over 15 m in the non-linear sprint test and leads to the conclusion that soccer players can accelerate better than rugby players over distances of up to 15 m, although no significant difference was observed between soccer and rugby players over the total distance of the non-linear sprint (FLT Z-Run Sprint) test.

The difference in non-linear sprint performance between soccer and rugby players may also be related to the total amount of sprinting activity involving changes in direction and to the number of turning movements that occur during the game. This argument is supported by the results of previous studies, which reported that total sprinting times involving turns are higher in soccer games than in rugby games. For example, (Bradley, et al., 2009) reported that soccer players covered 1253 meters while sprinting in soccer games. However, (Cunniffe, et al., 2009) reported that rugby players typically covered 837 meters while sprinting in rugby union games.

Based on the findings of time-motion analysis presented the previous studies of (Bradley, et al., 2009; Cunniffe, et al., 2009), it cannot be asserted that non-linear sprint performance is definitely related to the total number of turn runs, because there is no available data on the total distance covered by German soccer and rugby players. The observed differences might also be caused by differences in the speed-training methodologies or philosophies of soccer and rugby union teams.

Finally, it must be recognized that basic movement patterns in soccer and rugby union sports require good players who perform rapid movements with their limbs with multidirectional movements. The ability of the player to change direction successfully depends on factors such as visual processing, timing, reaction time, perception, and anticipation. The importance of these factors was observed in previous studies, in which it was hypothesized that agility performance reflects a more complex motor task than linear sprint performance, involving as it does change of direction and speed (technique, leg muscle qualities and anthropometry) as well as perceptual decision-making (visual scanning, knowledge of the situation, pattern recognition and anticipation) (Sheppard & Young, 2006).

However, previous studies in soccer have suggested that the importance of cyclic running is related to deceleration in accordance with changes in the structure of play. Due to the fact that action is limited to a narrow field, acyclic speed and dribbling can be more important in taking opponents out of play and gaining an advantage (Muniroglu, 2005). Therefore, speed drills should include both acyclic and different dribbling so as to more directly support the necessary skills required in modern soccer.

Based on the foregoing results, it can be concluded that soccer and rugby union coaches should adapt their training to provide highly specific cyclic and acyclic training that recognizes the specific demands of each game. This training will allow the staff trainers to set individual programs for players with the goals of improving their ability to accelerate and increasing their maximal velocity during sprints. This training program may require guidance in running technique in addition to development of the relevant energy systems.

5.3 Strength

In this section in discussion, the mean of one repetition maximum bench press (1RMbp) and back squat (1RMbs) will be discussed for both team field sports players.

5.3.1 Bench press (1RMbp)

In this part of the discussion, the means of one-repetition maximum absolute and relative (1RMbp) tests of the soccer and rugby players in the current study will be compared with each other and with the mean scores of elite and professional players reported in previous studies. The relative mean of the (1RMbp) test was calculated by (Allometric scaling⁷) of previous literatures. The mean absolute (1RMbp) of soccer players in the current study was 87.86 ± 12.20 kg and relative to body mass 4.51 ± 0.43 kg^{0.67}. According to previous studies, the mean (1RMbp) of soccer players in elite and professional levels reported range mean between 65.3 ± 1.5 to 85.38 ± 9.89 kg, (Tab. 17, p. 76).

The absolute mean (1RMbp) score of the soccer players in the current study was higher than the absolute mean (1RMbp) scores of soccer players from all other national leagues; in particular, it differed by 2 kg from the mean (1RMbp) score of Bundesliga players in the recent study of (Freiwald & Baumgart, 2012). However, the soccer players in the current study had mean relative (1RMbp) scores that were similar to those of 4.5 ± 0.53 kg^{0.67} (Freiwald & Baumgart, 2012). In addition, the mean relative 1RMbp score of the soccer players in the current study was similar to that of elite Norwegian first-league players, which was 4.6 ± 0.7 kg^{0.67}, although the absolute mean score of Norwegian players was higher by 5 kg.

The difference between the absolute mean (1RMbp) score of the soccer players in the current study and that reported by (Freiwald & Baumgart, 2012) for the Bundesliga soccer team was small (2 kg); it was similar to the difference from

⁷ Dimensional scaling suggest that comparisons between a small and bigger players should be expressed by (kg) body weight raised to the power of 0.67 as $\text{kg (1RMbp)} / (\text{kg body weight})^{0.67}$. If dimensional scaling is not used, maximal relative strength underestimates the big player and overestimates the small one (Wisloff, et al., 2004; Wisloff, et al., 1998).

the mean value reported by (Wisloff, et al., 1998) for soccer players in the first Norwegian league (5 kg). However, all three teams showed relatively similar relative mean of (1RMbp) $\sim 4.5 \text{ kg}^{0.67}$, although the Norwegian players' mean body weight was lower by 3-5 kg than that of either German team.

The difference between the soccer players in the current study and those in previous studies in mean absolute (1RMbp) may be explained by the differences in strength training of soccer players from different national leagues. The difference may also be caused by the similarities between training and testing exercise repetitions. In addition, external factors such as genetic factors or differences in the natural environment may partially explain these findings.

In soccer, Germany is classified at a higher level than other teams, including those of Hong Kong, Greece, and Ireland. Germany was ranked at the 3rd level in the world ranking of soccer players, while the other nations studied were ranked lower. These facts support the idea that soccer players in high-level leagues are stronger than players who compete at lower levels, and they are consistent with the observations of (Wisloff, et al., 1998), who reported that first-league players lifted higher absolute (1RMbp) mean $82.7 \pm 12.8 \text{ kg}$ than team players $77.1 \pm 16.5 \text{ kg}$ who were elevated to the elite soccer league in Norway after 8 years of playing at second-league level. Differences in the intensity of strength training and in the number of repetitions and strength training sessions may also partially explain the differences in the mean 1RMbp scores of national leagues. (Wisloff, et al., 2004) indicated that the number of repetitions during strength training could be different in the strength training strategies used in high- and low-elite soccer leagues.

The comparable results showed no wide difference between soccer players in the current study and those in the studies of (Freiwald & Baumgart, 2012; Wisloff, et al., 1998) in relative mean to body weight, although Norwegian players' mean relative (1RMbp) score was 5 kg less than that of the soccer players in the current study. This small difference between German and Norwegian soccer players may be related to the number of participants and their

strength- training activities. In the study of (Wisloff, et al., 1998), strength training was performed on an individual basis without any supervised regimen. In that study, players performed (1RMbp) as part of their normal strength training programme; however, 9 of the players received additional advice from the research group and consequently integrated a twice-a-week strength training programme into their normal schedules.

Generally, for soccer players, upper body strength is not as important as lower body strength. It could be said that a soccer player need not be able to bench press more than his own body weight; in fact, a player with too wide an upper body or too large an amount of upper body muscle might sacrifice speed or agility to a certain extent, especially when sprinting and turning while in possession of the ball.

The mean absolute (1RMbp) of the rugby players in the current study was 100.71 ± 15.30 kg and relative to body mass 4.91 ± 0.61 kg^{0.67}. According to previous studies, the mean (1RMbp) of rugby players in elite and professional levels ranges between 99.15 ± 1.5 and 146.8 ± 11.50 kg, (Tab. 19, p. 80). The mean absolute (1RMbp) for the rugby players in the current study was lower than the mean absolute (1RMbp) for rugby players from all other national leagues, while the mean relative (1RMbp) was similar to the Irish players' value of 99.15 kg.

In contrast to the results for the soccer players, who scored relatively better on the (1RMbp) than players in all the other national soccer leagues, the rugby players in the current study, as mentioned above, had the lowest mean (1RMbp) of rugby players in all national leagues. The difference in bench press scores between rugby players in the current study and those in other national leagues could be explained in a similar way as the differences observed for soccer players. Factors such as higher or lower levels of competition, training session hours and the relative intensity of strength training may explain the differences in (1RMbp) scores between rugby players in the current study and players from

New Zealand and Australia, for whom mean absolute (1RMbp) of ~ 140 kg and ~ 141 kg, respectively, were reported.

New Zealand and Australian rugby players have always competed and participated in the World Cup, and these countries have the top rugby leagues in the world. Based on their experience, which is undoubtedly superior to that of German rugby players, these teams likely place great emphasis on developing players' upper body strength, which is very important and is related to the development of a high level of skill in rugby. Because these countries participate at the top competition levels, the players on their teams need to be able to engage in good contact while mauling or scrumming and must be able to use their upper bodies for these skills when in contact with the opposing players. Thus, players on these teams are likely to have better upper body strength ability than German rugby players. This is reflected in the higher mean (1RMbp) of players from other national leagues compared to that of German rugby players.

The observed difference in (1RMbp) test scores between top-level players such as New Zealand and Australian players and German rugby players is consistent with the results of previous studies, which have indicated that rugby players in top-level competitions lift more weight in (1RMbp) than players at lower levels. In the study of (Baker, 2001), professional rugby players in (1RMbp) test lifted ~ 23 kg than amateur rugby players, 134.8 ± 15.2 kg and 111 ± 15.2 kg, respectively.

Based on the foregoing results, German rugby union coaches must improve their strength-training strategies so as to improve the upper body strength of their players. Improvement in players' upper body strength through training will also improve the players' contact skills, an important success factor in rugby union games. In addition, it must be taken into consideration that the strength characteristics profile is an important factor in selecting sub-elite players who will participate at high competition levels.

The results of the current study showed a significant difference between soccer and rugby players in scores on the absolute (1RMbp) test ($p \leq 0.05$); however,

no significant difference between the two groups of players in (1RMbp) test score relative to body weight was observed ($p \geq 0.05$). Rugby players achieved higher absolute and relative mean scores on the (1RMbp) test 100.71 ± 15.30 kg and 4.91 ± 0.61 kg^{0.67}, respectively, than soccer players 87.86 ± 12.20 kg and 4.51 ± 0.43 kg^{0.67}, respectively.

Comparison of the mean (1RMbp) test scores of elite and professional soccer and rugby players in previous studies, which are shown in (Tab. 17 and 19 (p, 76 and 80), and report higher mean scores on the (1RMbp) strength test for rugby players than for soccer players, supports the results of the current study. In addition, these results are consistent with those of previous studies, which indicated that rugby players outperform soccer players when measured in the absolute (1RMbp) strength test. A comparative study of football codes by (Brick & O'Donoghue, 2005) reported that rugby players had a higher mean absolute (1RMbp) strength test score 99.15 kg than soccer players, who lifted 80 kg, a difference of ~ 19 kg in the mean scores of the two sets of players.

According to previous studies and the results of the current study, rugby players were stronger than soccer players when assessed in the absolute (1RMbp) strength test. This finding may be explained by the nature of rugby union sport, which needs strong players. During games, rugby players spend more time in contact situations such as scrummaging and mauling. The results of previous studies support this explanation, (Deutsch, et al., 2007) investigated the percentage of time spent in these skills in rugby union games. The results confirmed that contact skills in rugby games represented 47-49 % of the total time during which activity skills were used in the game. In contrast, soccer players performed most skills in the game without spending a high percentage of time in contact with opposing players.

Therefore, it could be said that nature of particular sports is related to the particular physical fitness characteristics such as upper body strength. For example, a study by (Durandt et al., 2007), who compared soccer and field hockey players, reported a significant difference between field hockey and

soccer players in absolute (1RMbp) scores 82 ± 16 kg and 65 ± 13 kg, respectively; as well as in relative scores 7.0 ± 1.1 kg^{0.57} and 5.6 ± 0.9 kg^{0.57}, respectively, representing percentage differences of 21% and 20%. The authors explained this finding based on the fact that the nature of field hockey demands that requires players wield their sticks as part of the game. In addition to the above explanation, upper body strength is important in rugby union, in which all game activities involves pushing and pulling during play. Thus, it can be concluded that rugby players require a higher level of upper muscular strength than soccer players.

The mean score on the relative (1RMbp) strength test did not differ significantly between soccer and rugby players. This finding can be explained by the insignificant body weight difference between soccer and rugby players in the current study. In addition, the rugby players in the current study were observed to be generally lighter than the players in most other national rugby leagues, although body size plays an important role in success in rugby union games. The lower upper-body strength of rugby players compared to soccer players in the current study can also be explained by this finding.

Finally, soccer fitness tasks do not require the same strength as rugby union tasks. In soccer, there is more emphasis on the skills needed to retain possession of the ball and less emphasis than in rugby on upper body strength; soccer also differs significantly from other football codes. In addition, the difference in upper body strength between rugby and soccer players, which indicates a greater level of strength conditioning in rugby union, may be caused by adaptation to training and competition. The trends and differences in upper body strength between players of the two sports in the current study and players of other football codes could be characterized with respect to the physical fitness abilities of the players in each of these particular field team games and the nature of each football code sport.

5.3.2 Back squat (1RMbs)

In this part of strength discussion and with respect to different (1RMbs) test protocols, the mean (1RMbs) test scores will be compared between elite and professional soccer and rugby players according to previous studies in (Tab. 17 and 19, (p, 76 and 80). In previous studies, the mean (1RMbs) score of soccer players in elite and professional levels ranges between 123 ± 1.5 and 171.7 ± 21.2 kg. In addition, the mean (1RMbs) of rugby players in elite and professional levels ranges between 147.9 ± 26.8 and 189.63 kg.

Based on the mean scores of elite and professional soccer and rugby players in the (1RMbs) test in previous studies, the mean differences in absolute (1RMbs) was ~ 18 to 24 kg for elite-level and professional players. This confirms that rugby players possess greater lower-body strength than soccer players and is consistent with the results of a previous study by (Kuhn, 2005), who, in a comparative study of football codes, reported that rugby players had significantly higher absolute upper leg strength scores than soccer players, although the relative strength scores of players of the two sports did not differ.

This finding may be explained by differences in the nature of the two sports. Rugby players spend more time in upper body contact with opposing players and use the lower body to push the opposing players in contact skills such as scrumming. This skill, which is important in rugby, requires more power and strength conditioning of the legs. On other hand, most soccer actions are carried out with the legs but in a different way from the actions of rugby players. In soccer, the leg muscle must have sufficient basic strength to allow a player to shoot and jump. This difference in the nature of the two sports is reflected in the different aims of lower body training in the two team field sports.

The previous studies support this explanation, (Bangsbo, 2003) indicated that, strength training can be advantageous for soccer players. However, there can also be negative effects if the training is not well-structured. If too much muscle mass is gained, the player may lose soccer-specific technical skills. In rugby, (Crewther, et al., 2011) indicated that larger body mass may reflect muscular

adaptation that occurs as a function of the strength requirements of the game, enabling players to withstand and transmit the forces applied while scrumming.

To summarize the findings regarding strength, field team sports such as soccer and rugby are classified as sports that relate highly to strength. This categorization indicates that field team sports are not single-task performances; instead, they involve many tasks and skills, some of which require strength without being strength limited and others that require little strength without being strength-independent.

In sports, the term "strength" refers to the generation of forces or torques during specific movements (Bompa & Haff, 2009). Therefore, it should be noted that wide differences between soccer and rugby players in lower body strength exist that are related to the nature, positional roles, specific skills, physical contact and rules of the two sports. These different requirements may further differentiate the players according to the strength demands made on them during the game and further influence the application of player strength to specific performance tasks.

5.4 Endurance

In this part of the discussion, the mean maximum oxygen uptake VO_{2max} of the soccer players in this study, estimated using the (FLT VO_{2max} test protocol), which involves the use of a motorized treadmill, will be compared with VO_{2max} values that have been reported in previous studies of soccer players. In addition, the mean VO_{2max} of rugby players in the current study estimated using the (3-km run field test) will be compared with the means of VO_{2max} reported in previous studies of rugby players.

The mean VO_{2max} of the soccer players in the current study was 52.16 ± 3.05 $ml \cdot kg^{-1} \cdot min^{-1}$. In previous studies, the mean VO_{2max} of the soccer players in elite and professional levels reported ranges between 51.3 ± 4.4 and 67.6 ± 4.0 $ml \cdot kg^{-1} \cdot min^{-1}$, (Tab. 23, p. 89). The mean VO_{2max} of the soccer players in the current study was lower than that of players in most other national soccer leagues; it was similar to the lowest mean value 51.3 ± 4.4 $ml \cdot kg^{-1} \cdot min^{-1}$, that

was reported by (Brick & O'Donoghue, 2005) for Irish players and exactly the same as the mean value of $52.5 \pm 7.5 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ reported by (Da Silva, et al., 1999) for Brazilian players.

Thus, the soccer players in current study were found to be weaker in $\text{VO}_{2\text{max}}$ than soccer players in other national leagues. This could be due to several reasons including performance testing time, different testing protocols, and differences in the number of soccer players who participated in the studies. Similar explanations were suggested by (Reilly & Gilbourne, 2003; Stolen, et al., 2005). In these studies, it was suggested that the measured $\text{VO}_{2\text{max}}$, of soccer players is influenced by fitness time testing and is also to some extent associated with the positions of the players within the team, and the coefficient of variation is relatively modest, amounting to 7.8% among the elite teams.

There is another important factor that might explain the observed difference in $\text{VO}_{2\text{max}}$ between soccer players in the current study and those in other national soccer leagues. The difference might be related to the total distances covered in soccer games.

Players in the current study covered fewer kilometers than other players in other national leagues. Previous studies, which report a relationship between total covered distance in soccer games and the players' mean $\text{VO}_{2\text{max}}$ values, support this explanation. (Wisloff, et al., 1998) suggested that, if the average $\text{VO}_{2\text{max}}$ in a team is $6 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ greater than that of their opponents, it would be equivalent to having an extra player on the field in terms of the distance covered. In addition, the study of (Helgerud, et al., 2001) found that after 8 weeks of intense aerobic conditioning, $\text{VO}_{2\text{max}}$ increased from $58.1 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ to $64.3 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$, and video analysis demonstrated that this increased aerobic capacity was associated with an increase in the distance covered by players during the match from 8.619 ± 1.237 to $10.335 \pm 10.335 \text{ m}$.

The mean $\text{VO}_{2\text{max}}$ of rugby players in the current study was $53.8 \pm 3.40 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$. In previous studies, the mean $\text{VO}_{2\text{max}}$ of rugby players at the elite and professional levels ranges mean between 52.7 and $61.9 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$, (Tab. 27,

p. 99). The mean VO_{2max} of the rugby players in the current study was similar to that of players in most other national rugby leagues; for these players, reported mean VO_{2max} fell between 53.3 and 56.85 $ml \cdot kg^{-1} \cdot min^{-1}$. However, it was lower than the mean VO_{2max} values for British and Italian international players, which ranged between 58.4 and 61.9 $ml \cdot kg^{-1} \cdot min^{-1}$, respectively.

Taking into consideration that certain factors, which include distance covered and the use of a variety of endurance testing protocols, have been shown in previous studies to influence VO_{2max} , the rugby players in the current study do not differ widely in VO_{2max} from rugby players in other national leagues, who were assessed by endurance field testing protocols such as the interval shuttle run test and the 3-km run test. The mean VO_{2max} of rugby players in the current study was $\sim 8 ml \cdot kg^{-1} \cdot min^{-1}$ lower than the mean VO_{2max} of Italian rugby players, which was $61.9 \pm 7.1 ml \cdot kg^{-1} \cdot min^{-1}$. The difference in mean in VO_{2max} between rugby players in the current study and the Italian players may result from the use of different testing protocols.

The mean total time for the 3-km run test of the rugby players in the current study was poorer than the reported mean for professional rugby players. The rugby players in the current study scored a mean time of 12.80 ± 1.01 min when completing the 3-km run endurance field test; this is outside the range of 11.15 to 12.00 min reported for male international rugby players (Luger & Pook, 2004) and outside the range of 11.50 to 12.50 min reported for professional Welsh players (Welsh, WRU). This finding may be explained by the level of competition in which these teams engage; German rugby players were ranked at a lower level in the IRB world ranking table.

Rugby players who competed in high-level competitions covered more total distance than players who competed in lower-level competitions. This may also explain why the rugby players in the current study had weaker scores in the 3-km run test than British players, who competed in high-level competitions. Previous studies support this explanation. (Roberts, et al., 2008) reported a mean covered distance per game of 5.854 m for elite English players, while sub-

elite players covered a mean distance of 4.940 m. The relative importance of being a high- or low-level player and the total covered distance in rugby games to VO_{2max} scores, however, is unclear; to my knowledge, no studies have investigated the relationship between total covered distance and VO_{2max} in rugby.

According to previous studies, the mean VO_{2max} of soccer players at the elite and professional levels ranged between 51.3 and 67.6 $ml \cdot kg^{-1} \cdot min^{-1}$, (Tab. 23, p. 89). In addition, the mean VO_{2max} of rugby players at the elite and professional levels was between 52.7 and 61.9 $ml \cdot kg^{-1} \cdot min^{-1}$ (Tab. 27, p. 99). The mean difference between soccer and rugby players was $\sim 5-6 ml \cdot kg^{-1} \cdot min^{-1}$. This difference in the mean VO_{2max} values of soccer and rugby players in previous studies confirms that soccer players are superior to rugby players in aerobic capacity.

This finding is consistent with the results of previous studies. (Helgerud, et al., 2001; Stolen, et al., 2005) found that the VO_{2max} of male soccer players varied from 50-75 $ml \cdot kg^{-1} \cdot min^{-1}$ and that players typically covered 8-12 km distance during soccer games, while rugby players had VO_{2max} values ranging from 51.8 to 59.6 $ml \cdot kg^{-1} \cdot min^{-1}$ and covered 5.2 to 7.2 km during match games (Duthie, et al., 2003; Reilly, 1997).

There are additional possible reasons for the observed differences between soccer and rugby players in aerobic capacity. These include total covered distance, the percentage of game time spent in high-intensity activity, and the natural demands of the game for each sport. Soccer players sprint and run for greater distances than rugby players and spend more time in high-intensity activity during games. In addition, soccer games are 90 min in duration, while rugby union games last for 80 min. These reasons likely also contribute to the superiority aerobic capacity of soccer players compared to rugby players.

The total distance per game covered by soccer players reflects their high estimated VO_{2max} , which is higher than that of rugby players, who cover shorter distances per game. This explanation is consistent with the results of a

comparable study by (Duthie, et al., 2003), who suggested that in rugby a high VO_{2max} may not be a priority compared to other sports such as soccer because VO_{2max} is related positively to the covered distance, level of work intensity, number of sprints and involvements with the ball.

The nature of rugby union sport reflects less need for high aerobic capacity than soccer because rugby players spend more time in low-intensity activities that involve contact skills such as scrumming, mauling and rucking. In contrast, soccer players spent more time running and sprinting with the ball. This explanation has been confirmed in previous studies of soccer and rugby.

(Deutsch, et al., 2007) suggested that rugby players spend 85% of time during matches in low-intensity activities such as standing, walking, jogging and utility movements and 15% of the time in high-intensity activities such as cruising, sprinting, scrummaging, rucking, mauling, and tackling. However, in soccer (Bangsbo, et al., 1991; Mohr, et al., 2003) suggested that during a 90-minute game players generally spent approximately 40% of this distance high-intensity running and 1-11% in sprinting.

According to the match game performance demands of the two field team sports addressed in this study, which found differences between both sports activities and intensities in the game, it can be said that soccer players have a higher level of aerobic capacity than rugby players, even allowing for the 10-min shorter duration of rugby union games and for the differences in total distance covered during matches. The difference in the aerobic capacities of soccer and rugby players also indicates that a greater level of aerobic conditioning occurs in soccer; this may be due to an adaptation to training and competition.

5.6 Correlations between physical fitness variables for soccer and rugby players

In this part of discussion, and in accordance to data that collected of physical fitness characteristics testing protocols in soccer and rugby players. Person product moment correlation coefficients were used to determine the relationships between sprint, strength and endurance test variables.

5.6.1 Relationships between physical fitness variables in soccer

The results of the current study showed significant correlations between soccer players' times in the 5 m linear sprint and in the 10 m and 30 m sprints ($r = 0.93$, $p < 0.01$ and $r = 0.64$, $p < 0.05$, respectively) and between players' times in the 10 m and 30 m sprints ($r = 0.61$, $p < 0.05$). For the non-linear sprints, the current study showed significant correlations between times in the 8 m sprint and times in the 15 m and 22 m sprints ($r = 0.98$, $p < 0.01$ and $r = 0.97$, $p < 0.01$, respectively) as well as between the 15 m and 22 m sprints ($r = 0.99$, $p < 0.01$). However, no significant correlations were observed between the sprint, strength and endurance variables (Tab. 42, p. 121).

The significant correlations between sprint performances in the 5 m sprint (first step quickness), 10 m sprint (acceleration) and 30 m-sprint (maximum speed) are consistent with the results of a previous study by (Little & Williams, 2005), who reported high correlations between acceleration and maximum speed in soccer players. This finding indicates that players who are fast over short sprint distances are also the fastest over 30 m, confirming that first step quickness and acceleration are vital for better sprint performance.

Another finding of the current study was that performance times for non-linear sprint distances of 8 m, 15 m and 22 m were significantly correlated. This finding indicates that, players who were fast over short sprint distances involving multidirectional turning movements were also the fastest over the 22 m non-linear sprint and confirms that good non-linear sprint performance over 8 m and 15 m distances with two turns to different sides is related to better sprinting over a 22 m course with multidirectional turns.

Linear sprint performance over a 30 m distance was not significantly correlated with non-linear sprint performance over a 22 m distance. This finding indicates that the performance of soccer players over linear 30 m and non-linear 22 m sprints are independent tasks. The negative correlation between these results is consistent with the findings of a previous study by (Little & Williams, 2005), who observed a weak correlation between acceleration and maximum running in a 20 m zigzag agility test in soccer players ($r = 0.35$ and 0.46 , $p > 0.05$).

The consistency between the findings of the current study and that of (Little & Williams, 2005) are also supported by the results of (Young, et al., 2001), who examined the specificity of training responses to straight sprint or agility training over a 6-week period and found that a training method specific to one speed quality produced limited transfer to the other. In addition, (Little & Williams, 2005) presented preliminary data on professional soccer players that suggests that acceleration, maximum speed and agility are relatively independent qualities.

From the data discussed above, it can be seen that non-linear sprint performance with sideways turns in soccer players over a 22 m distance is not related to the linear sprint performance of these players over a 30 m distance. In soccer, the importance of linear running has increased because of changes in the structure of play. Because action is limited to a narrow field, non-linear sprint performance and dribbling with the ball are very important in taking opponents out of play and getting an advantage. Thus, knowledge of the relationship between sprinting performance at various distances would allow coaches to structure soccer training more specifically by focusing on speed drills that include both acyclic and different dribbling, which more directly supports the demands of modern soccer.

The relationship between performance on strength and endurance tests and speed performance, whether tested using sprinting over 30 m or the (FLT Z-Run Sprint) test, were not significant. The lack of correlation between these parameters conflicts with the results of previous studies, which found a strong

correlation between squat strength and 30 m sprint performance in elite soccer players (Wisloff, et al., 2004). However, they are consistent with the results of (Sporis et al., 2011), who found a weak correlation between squat strength and VO_{2max} ($r = 0.44$, $p < 0.05$). The weak correlations between physical fitness variables in soccer players and performance on specific tasks may be explained by position-specific anthropometric data and/or by the limited number of soccer participants in the current study.

This explanation is confirmed by (Hopkins et al., 1999), who suggested that the small range of the data obtained when dealing with relatively homogenous populations requires that large numbers of subjects be sampled to obtain sufficient statistical power to measure the relatedness of parameters. Therefore, to more accurately determine the possible relationships between physical fitness variables in professional soccer players, research involving a large number of subjects is required.

5.6.2 Relationships between physical fitness variables in rugby

For rugby players, the results of the current study showed significant correlations between linear sprint performances at all distances ($p < 0.01$). For non-linear sprints, there were significant correlations between performance in the 8 m sprint with performance in the 15 m and 22 m sprints ($r = 0.77$, $p < 0.01$ and $r = 0.60$, $p < 0.05$, respectively). The correlation between performance in the 15 m and 22 m sprints was $r = 0.83$ ($p < 0.01$). Significant correlations were also observed between linear 30 m sprint performance and non-linear 15 m and 22 m sprint performance ($p < 0.05$). Performance in the non-linear 8 m sprint was significantly correlated with performance on the strength (1RMbs) test ($r = -0.66$, $p < 0.05$). With respect to relationships between strength and VO_{2max} , the results showed significant correlations between performance on the 1RMbp and the 1RMbs strength tests ($r = 0.75$, $p < 0.01$). In addition, there were significant correlations between VO_{2max} and performance on the (1RMbp and 1RMbs) strength tests ($r = -0.60$, $p < 0.05$ and $r = -0.77$, $p < 0.01$, respectively; (Tab. 43, p. 121).

A strong correlation similar to that observed for soccer players was also observed for rugby players with respect to speed. For rugby players, there were significant correlations between sprint performances over all distances; the players who were the fastest over 5 m and 10 m were also the fastest over 30 m. The significant correlations between sprinting distances over 30 m are consistent with the results of a previous study by (Gabbett, et al., 2008), who reported a high correlation between acceleration and maximum speed over 30 m in rugby players ($p < 0.05$). The observed relationship between linear sprint parameters indicates that a good start and rapid acceleration are vital for rugby players in achieving good sprint performance.

Another finding of the present study was that the scores for non-linear sprint distances of 8 m, 15 m and 22 m were significantly correlated. This finding indicates that rugby players who accelerate well over short distances (8 m and 15 m) in non-linear tests such as the (FLT Z-Run Sprint) test are also fastest over the total distance in this test. This is an important finding in light of our previous work, which showed that the non-linear (FLT Z-Run Sprint) test is a strong indicator of playing level in soccer players. In addition, these data suggest that correlations between non-linear (FLT Z-Run Sprint) parameters share common physiological and biomechanical determinants in rugby.

The results for the non-linear (FLT Z-Run Sprint) test for rugby players are consistent with the results obtained in a previous study by (Green, et al., 2011). These authors reported a high correlation between acceleration and maximum speed over an agility test involving changes in direction by rugby players. The consistent findings of the current study and the study of (Green, et al., 2011) confirm that rugby union is a complex game that requires frequent short distance sprints with changes in direction in reaction to other players' movements during play.

The current study found a relationship between linear 30 m sprint distance and the 15 m and 22 m parameters of the FLT Z-Run Sprint test ($p < 0.05$). These results conflict with the findings of a previous study by (Young, et al., 2001),

who found linear and non-linear sprint performance to be independent variables and suggested that the relationship between linear sprinting performance and change of directional speed is weak.

However, the current results are consistent with the results of previous studies of rugby union players by (Gabbett, et al., 2008), who reported that the 5 m, 10 m and 30 m sprint times of these players were significantly correlated ($p < 0.05$) with their sprint performances in three different non-linear sprint protocols. In addition, (Ibrahim et al., 2012) found highly significant correlations ($p < 0.05$) between linear sprint distance times over 30 m with times for the L Run test in U19 elite rugby players.

The finding indicate that, rugby players who accelerate best over short distances 8 m and 15 m in non-linear tests such as the (FLT Z-Run Sprint) test are also fastest over the total distance in this test. Based on this finding, it can be concluded that cyclic and acyclic sprint performances influence each other positively and are not independent variables. However, it should be noted that factors such as visual scanning, anticipation and decision-making must be taken into consideration, as reported by (Young, et al., 2001).

Based on the foregoing, it can be concluded that players whose test results indicate lack of skill in changing directional speed require additional speed and change-of- direction speed training to improve their physical abilities. Knowledge of the relationship between linear and non-linear sprint performance in rugby would allow coaches to designed agility programs to improve these qualities and to use training strategies that are appropriate for rugby game demands.

In contrast to the lack of correlation between sprint performance and back squat strength observed for soccer players, the current study showed that for rugby union players there is a moderate correlation between performance on the non-linear sprint (FLT Z-Run Sprint) 8 m test and back squat strength ($p < 0.05$). However, no correlations between other linear or non-linear sprint distances with back squat strength were observed.

This finding indicates that acceleration during sprinting over the non-linear 8 m distance requires high force production. Players who have good strength in their legs can accelerate well in sprint performance during short distances during games; this is especially vital for rugby players. The current finding of a correlation between back squat and non-linear acceleration in rugby players' sprint performance over short distances is consistent with the results of a previous study of rugby players by (Baker & Newton, 2008), who reported that maximal leg strength and power were strongly related to agility sprint performance.

The relationship between the maximal back strength of rugby players and their performance in the 8 m non-linear sprint was significant, while that reported for the soccer players in the current study was not. The contrast between the soccer and rugby results may be explained by the strength training methodology used by each type of team player and by their differing body type profiles. Rugby training focuses primarily on upper and lower body strength training, both of which are good strength abilities that are widely recommended as underlying physiological abilities for rugby players. Increased leg strength and power would be expected to improve performance on non-linear sprints that involve changes in body direction. Therefore, the relationship between these two variables can also serve as an indication of player's optimal use of training sessions to improve their fitness.

With respect to strength, and VO_{2max} as predictive variables for performance on the 3-km run test in rugby players, the results showed a significant correlation between bench press and back squat strength ($p < 0.01$) as well as between VO_{2max} and bench press and back squat strength ($p < 0.05$ and $p < 0.01$, respectively). The observed correlation between bench press and back squat performance agrees with the results of a study by (Lange-Berlin & Ibrahim, 2009), who found a significant correlation between bench press and back squat performance in elite German rugby players four weeks after the beginning of the playing season. However, no significant correlation was observed in U19 sub-

elite players. The difference between elite and sub-elite players may be due to the methods of power training used by sub-elite players and their age level.

The significant correlation between bench press and back squat performance in the current study may be explained by the intensity of strength training for the upper and lower body that takes place in rugby. Rugby demands physical contact with the upper body and power training for the lower body so that players will be strong and able to push their opponents during contacts such as scrummaging. Few previous studies of rugby have investigated this point. Therefore, further investigation of this topic is necessary. It is recommended that strength coaches include this type of exercise and percentages in (1RM) during resistance weight training, in which the number of repetitions is an important variable.

The results of the current study also showed a significant correlation between back squat performance and estimated VO_{2max} in the 3-km run endurance test. This finding indicates that players with good back squat ability can achieve good values of VO_{2max} when completing the 3-km run test. Few studies have examined the relationship between estimated VO_{2max} in the 3-km run and back squat tests. The observed correlation between strength and endurance test results reflects the existence of a relationship between these factors. Strength and endurance are important qualities for rugby players and are necessary for tackling, pushing, pulling, and lifting tasks that often occur during a game. Therefore, players need to develop these qualities in various muscle groups. For example, abdominal endurance is of particular importance in contact sports because of the protective and stabilizing role of the abdominal muscles.

6. Conclusions and Recommendations

The aim of this thesis was to describe a physical fitness profile for soccer and rugby players with established normative data for German elite and non-elite male soccer and rugby players. In addition, to determine if there are any differences in physical fitness characteristics between soccer and rugby players. The conclusions will be according to the aim and objectives of the study, together with recommendations for specifically fitness profile for soccer and rugby players.

6.1 Conclusions

This study involved soccer and rugby players of the same mean age as top players who compete in high-level competitions. The fact that there is no significant difference in the mean age (24 years) of the soccer and rugby players in this study indicates high homogeneity between the two groups of players and provides an opportunity for a meaningful comparison of the physical fitness characteristics of these two groups of players. Based on the average age of players of these two field team sports in previous studies, it could be concluded that increases or decreases in age are related to the efficiency of physical fitness characteristics and to players' skills and abilities.

Measurement of anthropometric characteristics showed no significant differences in height or weight between soccer and rugby players, although soccer players were taller and rugby players were heavier. However, BMI differed significantly between soccer and rugby players. In general, the anthropometric profile is not an important factor for success in soccer, although it is useful when choosing players for particular positions. While it could be concluded that body size is an important success factor in rugby, body fat is a very important factor in soccer. Therefore, talent selection in rugby appears to be based on body size. In addition, differences in anthropometric profiles between players from different national leagues of field team sports are dependent on the nature of the sport, which needs every player when participated in these sports.

Soccer players were significantly faster than rugby players in linear sprints over 5 m, 10 m and 30 m. It could be concluded that acceleration and maximum sprinting ability are especially important for soccer players. In the literature, it was shown that these qualities are important in rugby for back players who attack and cover defense. Based on the results of previous studies, it could be concluded that soccer is a relatively continuous game that includes more passes, runs with the ball, dribbles, crosses, and other high-intensity activities than rugby. In addition, soccer games involve greater sprinting distances than rugby union games.

No significant difference was found between soccer and rugby players in non-linear sprint performance over 8 m, 2.Ch and 22 m, although significant differences were observed over 15 m and 1.Ch. In general, soccer players were faster than rugby players over all distances in the non-linear (FLT Z-Run Sprint) test. It could be concluded that the intensive lower body training received by rugby players enables them to start well and accelerate rapidly during non-linear sprints. Soccer players were also faster than rugby players in 15 m and 1.Ch. This suggests that soccer players spend more time running diagonally with the ball, while rugby players more often run laterally and in training have more reactive drills.

The thesis concludes that the ability to run fast in a straight line is not the same as the ability to perform cutting moves. It seems that, for both training and diagnosis in soccer and rugby, specific linear and non-linear sprint tests should be used. When testing the components of speed, specific tests should be used to assess the speed components that are important to the sport's particular demands. For elite soccer and rugby players, a 10 m test of acceleration, a 30 m test for maximum sprint and the FLT Z-Run Sprint test would be suitable. It is also likely that effective training methods to improve acceleration, maximum speed and agility will include specific training drills.

Based on the strength tests, the thesis concludes that the mean (1RM) upper and lower body strength of rugby players was higher than that of soccer players

due to the physical nature of the rugby game. Based on a comparison of our results with the results of previously published research, rugby requires players with strong upper and lower bodies due to the need for skills such as scrumming and mauling, which are highly related to strength. On the other hand, most soccer actions are carried out with the legs but not in the same manner as rugby actions. In soccer, the leg muscles must have sufficient basic strength to allow a player to shoot and jump. This difference in the nature of play in the two sports should be reflected in different goals for lower body training.

Based on the endurance results, it could be concluded that soccer requires more aerobic capacity than rugby. Previous studies showed that, soccer players exhibited a mean VO_{2max} that was $\sim 8-10 \text{ ml.kg}^{-1}.\text{min}^{-1}$ more than that of rugby players. According to this finding, it could be concluded that the difference in the aerobic capacities of soccer and rugby players indicates a greater level of aerobic conditioning in soccer. This may be due to the players' adaptation to training and competition. Soccer players covered more distance in match games (90 min) than rugby players (80 min) and spent more times in high-intensity activities, while rugby players spent more times in low-intensity activities. This must be taken into consideration in the talent selection process, when choosing players for field team sports.

The overall objective of performance testing is to evaluate a player in a sport-specific environment to identify his or her skill level and measure the effects of training. Identifying relationships between physical fitness variables allows soccer and rugby coaches and staff to choose appropriate tests and to maximize time and equipment use. This thesis concludes that speed, strength and endurance tests can identify potential for performance in complex sport-specific tasks such as those involved in soccer and rugby union.

With respect to the general conclusions of this thesis, the findings, together with collected results from the literature, reveal significant differences between players of soccer and rugby union sports and indicates that the demands of these two field team sports are different. These differences should be considered by those who design fundamental training and conditioning

programs for players of these sports. In addition, players who wish to participate in both of these sports should be aware of the differences in demands and activities of the two games they are preparing for.

6.2 Limitations of the study

This section outlines limitations associated with the research process that was undertaken in relation to the studies which make up this thesis:

1. The sample size used in this study was quite small meaning and the players could significantly differ from each other, due to individuality.
2. German rugby team was tested in Heidelberg. The Bundesliga soccer team was tested in Gelsenkirchen in their club, which have a performance diagnostic center that including five treadmills in laboratory. This possibility provided an easy way to measures aerobic capacity (VO_{2max} test) in laboratory. However, rugby players didn't have this possibility and measured according to the most reliable aerobic endurance test for elite and professional rugby players (3-km run) field test. In addition, the financial support in soccer team was more than rugby team.
3. Total covered distances during the soccer and rugby matches and training sessions were also not measured and back squat machines were not similar for both teams.
4. The generalization of the data may therefore not represent an accurate description for physical fitness characteristics experienced by soccer and rugby players.

6.3 Recommendations for future research

The following recommendations are made from the results, which obtained in this thesis. All data in the current study can provide important and useful information for coaches and players on the physical fitness requirements for soccer and rugby players during training sessions and matches.

- Future studies are needed to collect normative data of junior and sub-elite German soccer and rugby players in respect to anthropometric, speed, strength and endurance characteristics in order to facilitate talent selection and development.
- Future studies are needed to be conducted on elite and professional rugby players for development and extension the knowledge of coaches to ensure an improvement in the quality of the clubs rugby player's fitness for an overall increase in the standard of clubs rugby in Germany.
- Future studies are needed to use new technologies such as GPS system for soccer and rugby players to establish normative data in total covered distance, match performance activities (high or low intensities, sprinting,), and also nature of multidirectional movements in elite and sub-elite players for both field team sports.
- Future studies are needed to use linear sprint over 30 m and non-linear sprint (FLT Z-Run Sprint) test as standard sprint test batteries when measures soccer and rugby players to examined the relationships between cyclic and acyclic sprints for more success in training sessions.
- Future studies are needed to use non-linear sprint (FLT Z-Run Sprint) test to investigate the difference between another field team sports in acyclic sprint performance.
- Future studies are needed to determine the usefulness of regularly implementing recommendations based on laboratory and field testing results as part of player's seasonal training programme.

7. References

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