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Performance Assessment in Youth Soccer: an investigation of reproducibility and measurement error

This thesis is submitted in fulfilment of the requirements for the degree of MSc by research at the University of Glasgow

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BSc Hons .... October 2006

Abstract

Background: The introduction of new guidelines for the national club licensing certificate within Scottish Premier League (SPL) football clubs now requires the implementation of a sport science support programme for all SPL youth development teams. There are currently a limited number of publications available which focus on performance assessment in youth soccer players, and there is concern that methods in use with adult players may not be directly transferable to younger developing players. Before such an intervention can be implemented, it is essential to establish an appropriate means of performance assessment with an acceptable degree of measurement error.

Aim: To review the available literature on youth soccer performance and select an appropriate battery of performance assessments for use amongst the youth soccer population. Then to carry out a test retest investigation to determine whether the tests are reproducible and calculate confidence limits that will allow meaningful changes in performance to be detected in the future.

Methods: 76 young male soccer players were recruited from the youth development squads of 2 SPL clubs. Subjects underwent a battery of performance assessments which included: Squat Jump (**SJ**), Counter-movement Jump (**CMJ**), 10m & 20m (**10M & 20M**) sprint tests, 505-Agility tests with both left and right turn (**505-L & 505-R**) and 20m Multi-stage Shuttle Test (**MST**). Tests were performed on 2 occasions under identical conditions, with a period of 14 days separating test sessions. Paired t-tests were used to determine any systematic bias between test1 and test 2 scores, and where appropriate, 95% limits of agreement (LOA) were calculated using the methods of Band & Altman (1986).

Results: The SJ, CMJ, 505-L and 505-R test protocols were found to be reproducible with LOA of ±0.06m (SJ), ±0.06m (CMJ), ±0.32s (505-L) and ±0.26s (505-R). The repeat measures for the 10M, 20M and MST protocols were found to be significantly different indicating a systematic bias.

Conclusion: The broad limits of agreement for the SJ, CMJ and 505-agility test protocols suggest limitations in their use as a measurement tool for analysing changes in performance, as currently administered. It is recommended that further investigation of familiarisation and measurement error be carried out before further use of these tests.

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Acknowledgement

I would like to extend my appreciation to everyone who assisted me in the completion of this research. First of all, thanks to all the subjects for their hard work and commitment; I hope that the experience was enjoyable and has a positive effect on their future football careers. I would also like to thank Chris McCart, Kenny McMillan, Irene Riach, Adam Owen and all the management and coaching staff from the participating football clubs, as the entire project would not have been possible without their co-operation and assistance.

Special thanks to Ian Watt for all his hard work, encouragement and support, thanks to Dr Stan Grant for his academic advice, patience and understanding and to Tom Aitchison for his statistical advice (and love of a certain football club!). I would also like to thank all my friends and family who encouraged me throughout, always believing in my capabilities; with special thanks to B, M & D

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1 Introduction

Soccer (association football) is the most popular sport in the world (Reilly & Williams 2003, Stølen et al 2005), with over 200 million registered players worldwide and 205 countries currently affiliated with the world's governing body, the Federation of the International Football Association (FIFA 2005a). As well as vast participation in the sport, there is also an abundance of spectators. In the UK alone, professional clubs such as Manchester United, Liverpool, Celtic and Rangers regularly have attendances of around 40,000 to 60,000 fans for both domestic and European League matches. In addition, the extent of global interest in the game attracts a vast array of media coverage. Televised soccer events such as the 2002 World Cup in Korea, which amassed an average of 352.6 million viewers per match (FIFA 2005b), dominate the viewing figures of other sporting events, such as the 2004 Rugby World Cup, which averaged approximately 22 million viewers per match (BBC 2005).

Due to this popularity, the moneymaking potential in football has been recognised and embraced by many investors. According to figures published by Deloitte (2005), the top ten most lucrative football clubs in the world generated a combined income of over £2.3 billion during the season 2003 – 2004. In the UK alone, top earners Manchester United made £171.5 million (Delloitte 2005). This revenue is generated from many sources including ticket sales, television rights, sponsorship deals and merchandising. With financial rewards of this magnitude at stake, the pressure to succeed is immense, and clubs will pay staggering amounts to sign top-ranking players, with the record for the most expensive player transfer fee currently standing at £44 million (Deloitte 2005). In reality, there are few clubs in the world that can afford such extravagant spending, and the majority of clubs must rely on getting the best out of the players they have rather than spending millions in the hope of instant success.

Soccer and Science

Over the last 20 – 30 years, both time and money have been invested at top-level clubs to develop a systematic approach to soccer training. As a result, the demands of the game have been well documented and soccer-specific protocols for performance assessment and training are now widely in use at the more affluent clubs. Unfortunately this is not always the case with less-wealthy clubs, where it has been suggested that efforts to improve soccer performance often focus on technique and tactics, at the expense of physical fitness (Stølen et al 2005). As improvements in soccer-specific fitness have been proven to benefit soccer performance and the physiological capacities of players at the top level of the game continue to increase (Wisloff et al 1998, Casajus 2001), the failure of less successful clubs to adopt such techniques may see the gap between top and bottom increase.

Youth Development

In addition to its function with present-day players, scientific advances in soccer can also be applied to the development of future players. Financial investment in a youth development scheme that produces 'home-grown' talent can potentially alleviate the need to spend vast amounts of money in transfer fees in the future. In order to produce players who can meet the escalating physical demands of the game, the application of scientific training techniques should ideally be introduced during the early stages of a player's career. In 1997, the English FA introduced the 'Charter for Quality' criteria to all football academies and centres of excellence, which ensured the application of appropriate modern training techniques to the development of youth players at FA registered clubs (English FA 2006). With the country currently ranked 9^{th} in the FIFA world rankings (FIFA 2006), and the English national squad featuring many young talented players, these efforts appear to be generating rewards. No such criterion has been firmly established in Scottish football and the national team currently sit in 60th position in the FIFA world rankings (FIFA 2006).

According to the Scottish Football Association (SFA), Scotland has the greatest number of registered youth players among the European countries affiliated to FIFA, yet has the lowest proportion of adult players, which indicates a poor transfer of Scottish youth players into the professional adult game (Scottish FA 2005a). Within the leagues associated with the SFA, only the Scottish Premier League (SPL) has any criteria concerning sports science input. The National Club-licensing Certificate states that all SPL clubs must be able to demonstrate that they have access to qualified sport science expertise, with the designated provider monitoring a suitable youth development programme (Scottish FA 2005b). This guideline was only introduced at the beginning of the current season (2005/06), so at present, there are a number of Scottish clubs embarking on a new youth development training structure. As there is currently no department within the Scottish governing body to advise the clubs who are introducing sport science support to their football itinerary, we believe a source of reference is required.

Areas for concern

The basis of any successful programme to monitor and improve sports performance is a reliable method of performance assessment. It has been recognised that there are a limited number of publications that focus specifically on the young and adolescent soccer player (Williams & Reilly 2000), and there is a danger that the blind transfer of techniques devised for adult players may not be appropriate for the younger population. If performance assessments are to be introduced to youth development programmes then it is essential that the proposed methods are found to be appropriate and reliable.

The intent of the following research is to review the available literature on the physiological aspects of soccer in both adult and youth soccer players, identifying the most appropriate means of performance assessment for Scottish youth teams. Once protocols have been selected, measurement error will be investigated to establish the reproducibility of the tests and determine whether they are reliable as a means of performance assessment in youth soccer players. It is hoped that this work can contribute to the development of Scottish football as a valuable reference point to aid coaches and sports scientists in the implementation of future youth development programmes and raise awareness of the limitations of performance assessment.

2 Review of Literature

2.1 Requirements for Success

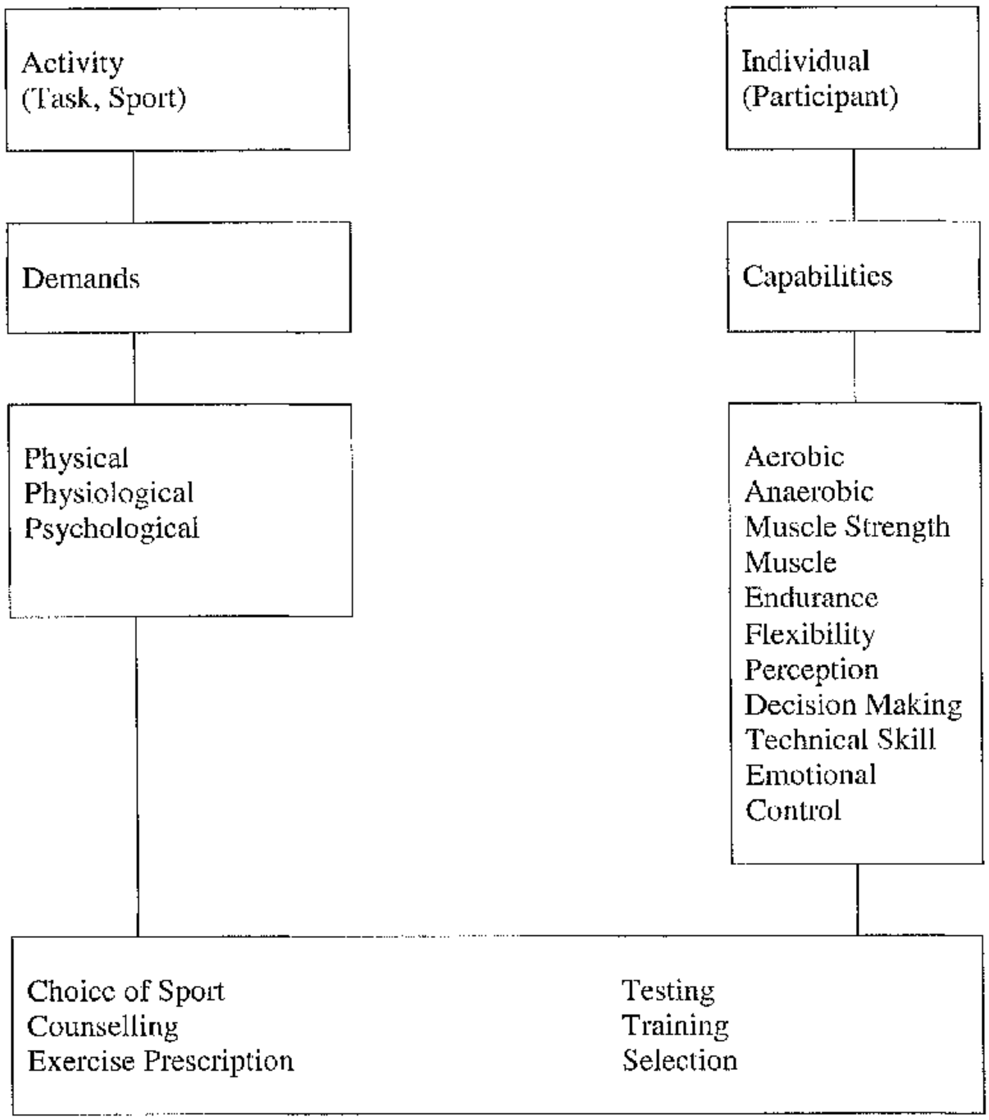


Figure 2.1 Ergonomics model of sports participation (Taken from Reilly & Williams 2003)

Success in competitive sport is the ultimate aim of the athlete. However, as most coaches and athletes will admit, there is no single determinant of success in any sport. According to Reilly & Williams (2003), the requirements for success in soccer play are multi-factorial, and should consider not only the player's technical soccer ability, but also physical, physiological and psychological factors. In agreement, Stølen et al (2005) also propose that soccer performance is dependant on all of the above, but include technical and tactical factors as foremost in importance. Figure 2.1 (Reilly & Williams 2003), illustrates how each of the relevant factors influence success in the game. The level of success attained will depend on a player's capabilities, which in turn will be influenced by the support and guidance given during the development process.

Individual soccer players will possess most of the described attributes to varying degrees, but not all will excel in each area. For example, a player may have a high aptitude for the technical skills of the game, such as ball control and tactical awareness on the field, but have poor emotional control leading to poor discipline and a lack of focus. Likewise, someone with a high degree of aerobic fitness and muscular strength may not possess the necessary ball skills to succeed in the sport. Of all the above attributes, the most important in a soccer sense, has to be the technical abilities of the player. Without the innate skill to perform the required actions of the game, all other attributes become redundant.

The nature of the game allows players to be weaker in certain attributes, which can be compensated for by alterations in team tactics during play, but it is beneficial to identify and attempt to correct weaknesses of a physiological nature. Sport science support programmes address physical preparation for the game, and can influence both the anthropometrical and physiological characteristics of a player in preparation to meet the demands of the game. Certain elements of physiological fitness have been shown to distinguish between elite and sub-elite players on many occasions, and the profiles of successful players can be a useful guide for players of a lower standard when identifying areas for improvement.

2.2 Demands of the Game

Observations from motion analysis, carried out on adult soccer players, show that an outfield player (all players with the exception of the goalkeeper) will take part in over 1000 short duration activities throughout a game (Reilly & Thomas 1976, Rienzi et al 2000, Mohr et al 2003), with a change in activity occurring approximately every 4 - 6 seconds. The activity is highly intermittent in nature and is often described in relation to the distance travelled during a match. There is a general consensus that the total distance covered in a 90-minute game is on average 10-12km (Ekblom 1986, Van Gool et al 1988, Bangsbo 1991, Rienzi et al 2000, Mohr et al 2003, Stølen et al 2005) although this will vary depending on factors such as playing position, match tactics, environmental influences and importantly, physiological capacity.

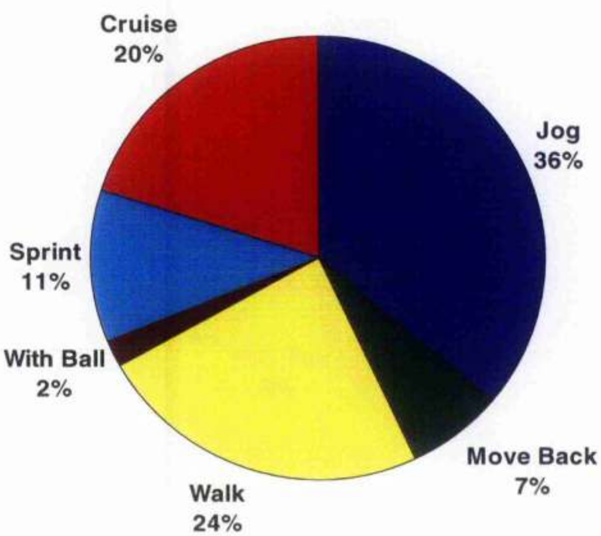


Figure 2.2 Relative distances covered in categories of activity during soccer match play

Figure 2.2 (taken from Reilly 2003) illustrates the different movement categories characteristic of soccer play, expressed as a percentage of the total distance covered. The movement categories are defined as follows: walking, jogging (non-purposeful, slow running), cruising (running with manifest purpose and effort), sprinting (goal-directed, very fast running) and moving back (travelling backwards - backing) (Reilly 2003, Strøyer et al 2004). Approximately 60 – 70% of the movements are classed as being carried out at low-moderate intensity including walking, jogging and backing. The remainder of match activity is considered to be high-intensity action which can be collectively referred to as high intensity running. An all out sprint is required about once every 90 seconds corresponding to approximately 11% of the total distance travelled.

Additional efforts hidden amongst these movement classifications incorporate: demanding changes of pace and direction including sideways and diagonal movements, explosive jumps during mid-air challenges, and kicking, heading and controlling the ball. Movement with the ball is only around 2% of the total distance travelled during the game. There are also numerous forceful efforts required to maintain balance and hold off opponents during physical challenges for possession. A review of soccer literature by Stølen et al (2005) concluded that on average, an individual player's match performance will include 10-20 sprints, 50 involvements with the ball, 15 tackles, 10 headers and about 30 passes. In order to be able to perform these actions on demand, soccer fitness training must focus on the development of game-specific strength, power and endurance.

Youth Players

The match criteria for the Scottish youth football league is essentially the same as the professional adult game, i.e. played with the same number of players per team, on a standard-sized pitch and lasting the regulation 90-minute duration. Some sources suggest that many football organisations world-wide adopt the principle of reducing pitch size and team numbers in an attempt to better match the demands of the game to the physical capabilities of the younger player (Stratton et al 2004b, Capranica et al 2001). However, it is apparent that this practice is not uniform throughout the football nations and certainly not at Premier League level in Scotland.

In spite of a global desire to maximise the development of youth soccer players, there have been very few investigations of the match demands and activity patterns of youth players and only 3 studies have been conducted using motion analysis to evaluate the youth game. Strøyer et al (2004) studied the match activity of 12-14 year old males and found game activity to be similar to that reported for adults. No differences were reported in relation to the distance travelled or the contribution of match activities such as sprints and jumps or involvements with the ball. This suggests that the physical attributes of strength, power and endurance will be as important to the outcome of the youth game as they are in adults.

In contrast, Capranica et al (2001) found 11-year old players to run more and walk less in an eleven-a-side match than adults, as did Thatcher & Batterham (2004) who found Under-19 premiership players to run more often than first team players. Both authors related their findings to shortcomings in technical skills and tactical awareness, and suggest that with less ability to read the game, the younger players make inappropriate tactical decisions and have to compensate by chasing the game. However, there are a variety of reasons why this may occur, and it is important to remember that the relative contribution of running and the total distance covered by adult players has also been shown to vary widely. As stated earlier, physiological status has also been shown to influence match performance so it is highly possible that the physiological differences between mature and developing players will be a contributing factor to these observed differences.

Before discussing the physiological components of soccer it is essential to consider the fundamentals of growth and development in order to gain insight into how the natural process of physical development may affect soccer performance in the developing youth player.

2.3 Growth and maturation

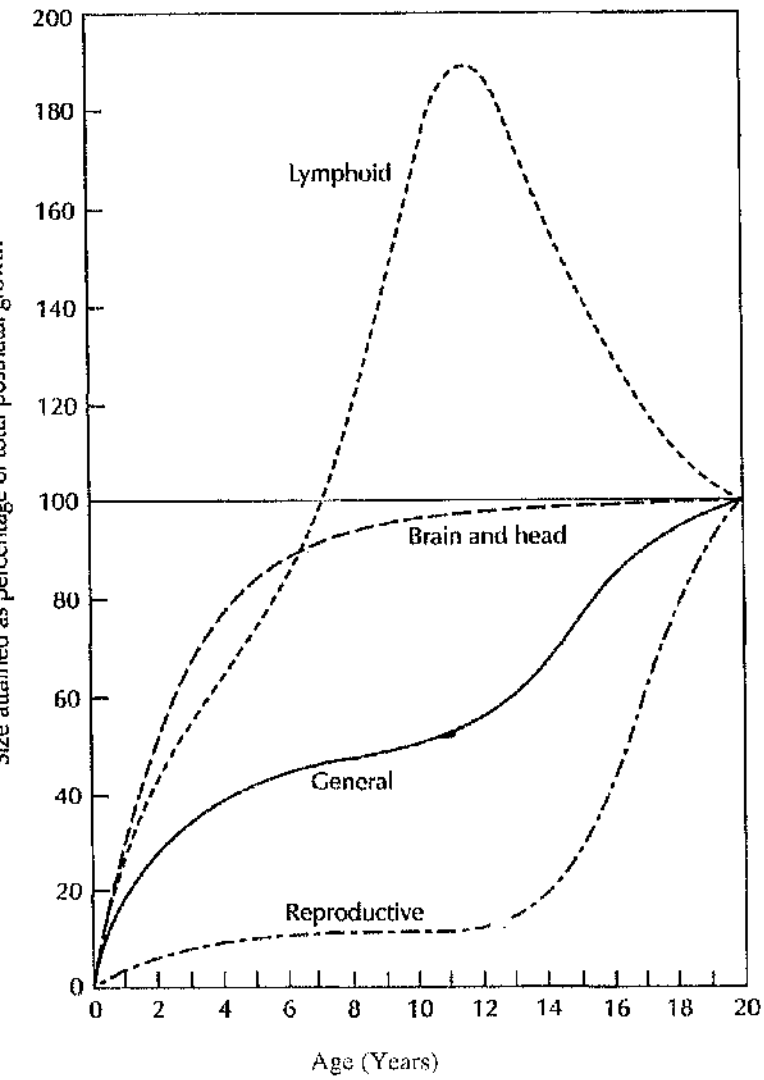


Figure 2.3 Scammon's growth curves, taken from (Stratton et al 2004a)

Patterns of Growth

The term growth refers to an increase in the size of the body or one or more of its parts, and is the most dominant biological process throughout the first 20 years of life (Stratton et al 2004a). The general pattern of growth from birth to the mature adult state is similar from one individual to another (Malina et al 2004a). Scammon's classic growth curves are used to illustrate this pattern (Figure 2.3). The different curves shown represent growth in the brain and neural tissue (neural curve), the immune system (lymphoid curve) and the sexual organs (reproductive curve), whilst overall growth in the size of the body i.e. height and weight is represented by the general curve; this curve is also representative of growth in the digestive and muscular systems and parts of the skeletal and cardio-respiratory systems.

A noticeable period of rapid growth occurs during the teenage years, evident in both the reproductive and the general curves in Figure 2.3. This marks the significant transitional period from the juvenile state to the mature adult state, which begins with the onset of puberty. Puberty is a result of hormone-directed changes within the body and is characterised by development of the secondary sex characteristics (Tortora 1999), achievement of the functional capacity for procreation and a noticeable spurt in physical growth (Malina et al 2004b). Certain aspects of athletic potential will increase throughout this period as a result of progressive gains in body size, fat-free mass and the size and function of the cardio-respiratory organs. The attainment of the mature adult state does not occur until around the conclusion of the teenage years (Stratton et al 2004a), so when considering youth soccer players, it can be assumed that all players are still likely to be progressing towards the fully mature state.

Maturity Associated Variation

Maturational progress is independent of chronological age. The timing and tempo of events during growth such as the age at the onset of puberty (timing) or the rate of gain in body mass (tempo) are highly variable and unpredictable. As a result of this variability, there can be substantial inter-individual differences in physical development at any given chronological age (Faigenbaum 2000). Given that soccer teams are grouped according to chronological age, there is a potential for large differences in maturity status and body size within a given team or football league.

Players can be classified as early, average or late maturing depending on the extent of their physical development. Measures of biological development can be made through 2 different means: radiographic assessment of skeletal maturity and clinical evaluation of sexual development based on the physical appearance of the secondary sex characteristics. Both methods have been reported in soccer literature, but there is a reluctance to use such methods on a large-scale due to both health-concerns and privacy issues (Malina & Cumming 2001).

Variations in maturity status can also be estimated using longitudinal anthropometric data to identify the attainment of specific maturational events, such as the age at the initiation of the adolescent growth spurt, or the age at peak height velocity (PHV) when the rate of height gain is at its maximum (Malina et al 2004b). Although such data can only be used retrospectively, knowledge of the behaviour of growth patterns and their effect on physical performance can aid the coach in understanding the physical disparities between players.

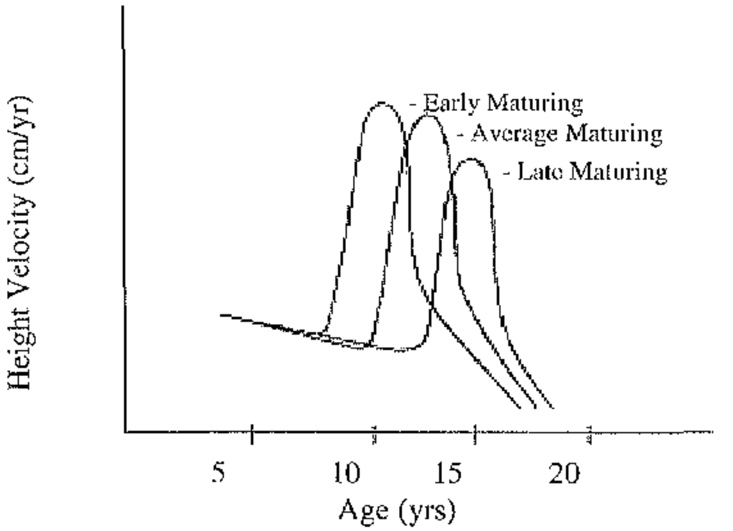


Figure 2.4 Early, average and late maturing growth velocity curves, taken from Stratton et al (2004a)

Figure 2.4 illustrates the general trend seen in the rate of height gain throughout the adolescent period. The onset of the growth spurt and the peak height velocity (PHV) can be easily identified on each curve. The 3 curves from left to right, known as growth velocity curves, are typical of early, average and late maturing players respectively. We can see that the 3 players will all go through the same stages of development, but that they all begin and end each phase at different times.

It is important that coaches understand that the failure of an adolescent soccer player to reach a given performance standard is highly likely to be related to growth and development and not simply poor athletic ability or lack of effort. Likewise, a young developing player will not respond to soccer play and training in exactly the same way that a fully mature adult will. Although the fundamentals of the game are essentially the same, the developing physiological systems will deal with the game demands in a different way.

2.4 Strength & Power

Chapter 2.2 discussed the physical demands of soccer detailing the contribution of power-based activities such as sprinting and jumping. Comparative studies of elite and non-elite soccer players have highlighted the importance of a player's strength and power capabilities to soccer success.

Superior strength in both the 1RM half squat and the 1RM bench press test has been found to distinguish between players from a league winning team and those finishing in last place of the same league (Wisløff et al 1998). Although aware of the limitations of their findings, the authors suggested that the superior strength base of the more successful team may have allowed for a better on field performance in power based activities which in turn, contributed to their success. Although this claim remains unsubstantiated, several findings provide support for this theory. In a recent study, maximal strength in the half-squat movement was shown to bear a significant correlation with both sprint and jump ability in elite soccer players (Wisløff et al 2004). This relationship between sprint and jump ability and soccer success has been indicated on more than one occasion; several studies have found professional players to possess faster maximal sprint times than amateurs (Brewer & Davis 1992, Cometti et al 2001, Kollath & Quade 1993) and one study has identified jump height as a predictor of team success in elite Icelandic players (Arnason et al 2004). Therefore it is a reasonable assumption that superior strength will contribute to soccer success; although further investigation is required before conclusions can be made.

Strength & Power in Youth Soccer Players

In sport in general, there is concern that children less advanced in physical development may be mistakenly considered to possess less athletic ability than those of the same age who are more mature in terms of their physical development (Lefevre et al 1990, Jones et al 2000). This view is shared by leading experts in youth football who suggest that players advanced in maturity are associated with advantages in size, fat-free mass, muscle mass, strength, power and speed (Malina & Cumming 2001).

Lefevre et al (1990) found early-maturing boys (as determined by the age at PHV) to perform significantly better in both static strength and explosive power tests than their late-maturing counterparts. Jones et al (2000) found similar results which could also be attributed to an anthropometric advantage, but were able to expand on the physical findings by including estimates of sexual maturity. A significant correlation was found between the stage of sexual development and performance in strength tests; with those most advanced in sexual development performing best. It was concluded that factors beyond the physical advantage of size were involved and that the increasing levels of circulating androgens (most likely testosterone) in those advanced in sexual maturity, would be accountable. In support of this, Faigenbaum (2000) suggests that a ten-fold increase in testosterone production during puberty in boys results in a marked increase in muscle mass and therefore brings about the potential to enhance strength and power abilities. These findings support the idea that an early maturing player would posses a significant advantage over a late maturing player in terms of the strength and power element of soccer play. This could potentially have an impact on many actions during the game, such as the maximum force that can be applied whilst kicking the ball for long passes, gaining height during aerial challenges, sprinting to gain a positional advantage and holding off opponents during challenges for possession.

The ability to perform the power-based activities involved in soccer will be as important to youth performance as they are to adult performance, however, the capabilities of a younger player will be heavily influenced by their developmental progress. Therefore it is important that coaches be aware of these limitations when comparing the capabilities of players within a given team and use performance assessment as a means of tracking an individual's development rather than a means of rating soccer ability.

2.5 Energy Demands

As stated earlier, soccer is categorised as an endurance sport, therefore the energy demands during a soccer game predominantly tax the aerobic energy systems (Reilly 1997). However, as the game involves many highly intensive bursts, there is also a substantial demand placed on the anaerobic energy systems. The average match intensity has been shown to be close to the anaerobic threshold, which is defined as the highest exercise intensity where the production and removal of lactate is equal (Stølen et al 2005). The ratio of aerobic to anaerobic exercise in terms of the distance travelled has been described as approximately 2:1 (Reilly & Thomas 1976), and the intermittent exchange between high and low intensity demand during soccer allows for the balance between lactate accumulation and removal to be maintained.

Key football research scientists have suggested that match intensity is equivalent to approximately 70 – 80% of maximal oxygen consumption ($\dot{V}O_2$ max) (Ekblom 1986, Reilly 1990, Bangsbo 1994a, Reilly 1997); however, a direct measurement of oxygen uptake during a live game has not yet been possible due to the extent of movement and physical contact involved in competitive play. Gas analysis during match simulation has been attempted (Ogushi et al 1993), but the equipment used for the collection of gas samples was shown to restrict movements and impair performance, thus making the results of the study inaccurate. Due to such limitations, estimations of match intensity have been based on measurement of heart rate response, which can easily be accomplished without detriment to performance. The average heart rate (HR) during a soccer match has been shown to be between 80 and 90% of maximum heart rate (Stølen et al 2005). Based on the linear relationship between oxygen uptake and heart rate response, $\dot{V}O_2$ during match play can be approximated by the use of regression equations in conjunction with $\dot{V}O_2$ /HR data collected under laboratory conditions. Balsom et al (1992) found evidence to suggest that HR increases disproportionately to $\dot{V}O_2$ during intermittent exercise as opposed to continuous activity, and suggested that this would result in an overestimation of match $\dot{V}O_2$ using the extrapolation method. However, further investigation by Bangsbo (1994a) has shown extrapolation of laboratory data to be a valid method for estimating energy expenditure during intermittent exercise with minimal error expected in translations from laboratory to field conditions; therefore the suggested intensity of 70 – 80% $\dot{V}O_2$ max is generally well accepted.

There is a common agreement that the relative intensity of match-play between elite and non-elite players is similar, i.e. 80 – 90% HR max or 70 – 80% $\dot{V}O_2$ max, but that the absolute intensity of play as indicated by the total volume of work done during a game, is greater for players at the top level of the sport (Ekblom 1986, Strøyer et al 2004). Players in higher-ranking leagues have been shown to cover more ground during a game and take part in more frequent and lengthy bouts of high-intensity exercise. This has been related to the superior aerobic fitness observed at the elite-level of the game, and the proven ability of aerobic training to improve soccer performance (Helgerud et al 2001).

Aerobic Power

As a consequence of the high dependence on the aerobic energy system, elite-level soccer players typically would be expected to demonstrate a high standard of aerobic power. Reilly et al (2000b) suggests that in order for a player to succeed at the top-level in soccer, maximal oxygen uptake ($\dot{V}O_2$ max) in excess of $60ml.kg^{-1}.min^{-1}$ should be expected. This value is similar to those found in players from other football codes such as rugby and Gaelic football (Reilly & Gilbourne 2003), but less than that of top-endurance athletes such as elite marathon runners, who have an expected $\dot{V}O_2$ max of $70ml.kg^{-1}.min^{-1}$ and above (Maughan & Leiper 1983). A wide range of values have been published for mean $\dot{V}O_2$ max in soccer players ranging from between 50 and $75ml.kg^{-1}.min^{-1}$ (Ekblom 1986, Reilly et al 2000b, Shephard 1999, Reilly & Doran 2003, Dowson et al 1999, Stølen et al 2005, Aziz et al 2004, Bangsbo 2004) although for those at the highest level this is more often between 60 and 70ml.kg^{-1}.min^{-1}.

There have been instances where $\dot{V}O_2$ max has been shown to distinguish between successful and less-successful teams. One investigation has shown that a championship winning team had a significantly higher mean $\dot{V}O_2$ max than that of the team who finished in last place of the same league (Wisløff et al 1998). Furthermore, a rank-order relationship was established between mean $\dot{V}O_2$ max and the first to fourth league placement in a top Hungarian League (Apor 1988). Whilst this is not conclusive evidence that a higher maximal aerobic power will determine success, it does highlight the importance of enhanced aerobic fitness, and its role in soccer performance.

Positional variations have also been suggested in relation to $\dot{V}O_2$ max. In general, it appears that the players covering the greatest distance on the field tend to have the highest maximal oxygen uptake. The midfield player is known to cover a greater distance on the field and several sources also describe the midfielder as having the highest maximal oxygen uptake (Reilly & Doran 2003, Tumilty 2000, Shephard 1999, Davis et al 1992). Central defenders have been found to have significantly lower relative values than midfielders, with fullbacks and strikers described as having intermediate values (Reilly & Doran 2003, Al-Hazzaa et al 2001, Wisløff et al 1988). There is much controversy as to whether this is a true variation according to position, or just a consequence of expressing $\dot{V}O_2$ max relative to body mass. Wisløff et al (1988) proposed that the $\dot{V}O_2$ max of defensive players will be underestimated in the ml.kg^{-1}.min^{-1} format, as studies suggest that these players are consistently found to be heavier than other outfield players. However, more recent anthropometrical data have failed to show the significance of such body mass variations (Hencken 2004, Bloomfield 2004).

Aerobic Power in youth soccer players

Maximal aerobic power ($\dot{V}O_2$ max) is dependant on a combination of factors. These can easily be explained in reference to the Fick principle, which is summarised in the equation below where $\dot{Q}$ is cardiac output, CaO_2 the content of oxygen in arterial blood and CvO_2 the content of oxygen in mixed venous blood:

$$\dot{V}O_2 = \dot{Q}\ (CaO_2 - CvO_2)$$

$\dot{V}O_2$ during exercise is ultimately limited by the available blood flow, the amount of oxygen available for extraction and the ability of the working muscles to extract and utilise O_2. In the immature youth soccer player, growth and development of both the cardiovascular system and respiratory organs will continually increase the potential for the development of aerobic power. The volume and mass of the heart are known to follow a growth pattern similar to that of body weight (Malina 2001). Increases in stroke volume from childhood values of 40ml to about 60ml have been shown to occur rapidly during the growth spurt (Stratton et al 2004a) and although heart rate is known to decline with age, the resultant effect is an increase in cardiac output (Malina et al 2004b). Increases in the oxygen carrying capacity of the blood and maximum voluntary ventilation also contribute to improvements in aerobic power (Stratton et al 2004a). Maximal aerobic power has been shown to increase with age, largely attributed to the increase in body size, and it is believed that $\dot{V}O_2$ max is more sensitive to aerobic training after the attainment of the PHV (Reilly et al 2000b). Therefore we would expect the training responses in a group of youth soccer players to vary in accordance with maturational status.

Reilly et al (2000b) suggest that values for $\dot{V}O_2$ max in adolescent soccer players are similar to those reported for young adults when expressed in the $ml.kg^{-1}.min^{-1}$ format. Few data sources are available but mean $\dot{V}O_2$ max in the range of 50 - 65 $ml.kg^{-1}.min^{-1}$ have been reported (Gil et al 2004, White et al 2004, Strøyer et al 2004).

2.6 Performance Assessment

Current sports science literature contains a wealth of publications on performance assessment. Methods in use with soccer players range from a simple measurement of the distance covered during a 12-minute run, to more complex lab-based tests, such as the soccer-specific intermittent treadmill protocol of Durst et al (2000). As soccer is dependant on a combination of fitness demands; which have been highlighted in the previous chapters, the preferred method is to utilise a battery of tests that evaluate performance in each of the relevant areas of fitness. The top science professionals involved in soccer recommend a combination of both laboratory and performance related field tests suggesting that clubs be selective, and opt to use tests where a change in test ability has been shown to positively influence match performance (Stølen et al 2005).

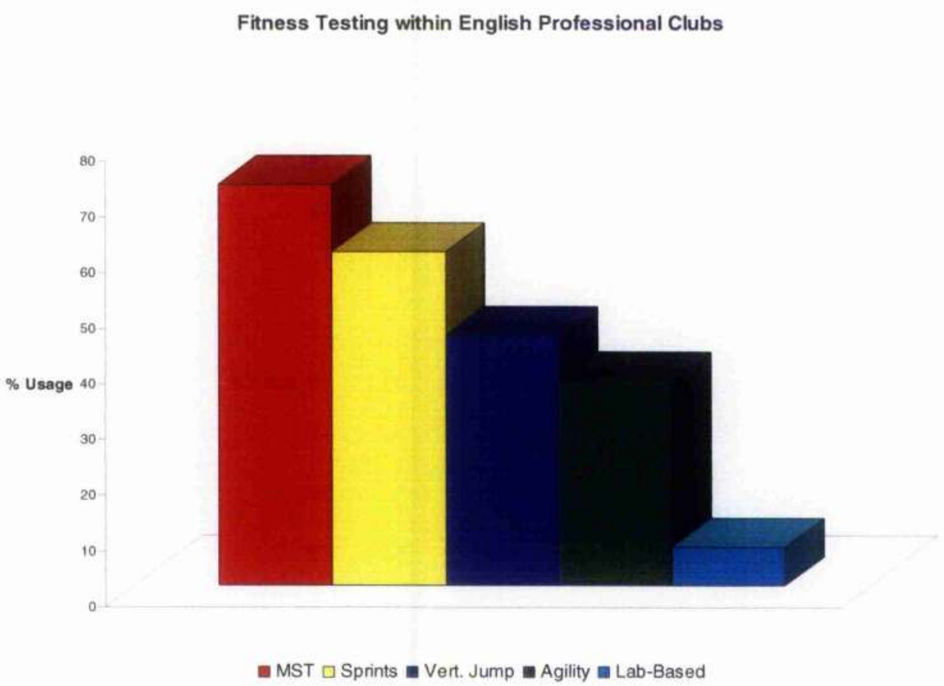


Figure 2.5 Prevalence of testing methods within English professional clubs.

Figure 2.5 illustrates data taken from a study by Erith (2004) representing the prevalence of various fitness testing methods within English soccer leagues. From this information it is clear to see that field-based procedures are more popular, with only 7% of clubs utilising lab-based tests. Although laboratory tests favour accuracy and reliability, they require specialist equipment, lengthy periods of time dedicated to each individual player, and the employment of expert personnel to carry out the procedures. As stated earlier, financial restrictions are the main limitation to the application of scientific techniques at many football organisations, therefore advanced laboratory procedures such as gas analysis and blood sampling are not readily available to players at less affluent clubs. In addition, these methods may be perceived as invasive and intimidating to players who are unfamiliar with the technical environment, leaving the use of such methods open to ethical debate. Both the financial and ethical issues make it difficult to consider laboratory assessments suitable for the younger football population.

In contrast, field-based tests are more specific to the needs of the sport and generally mimic actions involved in the game, thus providing a practical and non-threatening environment for the assessment of the younger player. They can also be easily administered to numerous players in one session, which is a more time and cost efficient means of testing large squads. The group setting can additionally be advantageous in boosting subject motivation.

Source	**Jump Ability**	**Linear Speed**	**Agility**	**Aerobic Endurance**
Tumilty (2000)	Vertical Jump (contact mat)	20m	505 agility test	MST
Hood et al (2002)	Vertical Jump (jump meter)	10m, 30m	Soccer-specific 35m agility run	1km time trial
Dowson et al (1999)	Vertical Jump (contact mat)	10m, 20m		MST
Franks et al (1999)		15-m,- 40m		MST
Casajus (2001)	Squat Jump Counter-movement Jump (force platform)			Laboratory measures
Reilly et al (2000a)	Vertical Jump (contact mat)	5, 15, 25, & 30m	40m agility run	MST
Chamari et al (2004)	Vertical Jump (force platform)	10, 20 & 30m		Laboratory measures

Table 2.1 Performance testing methods in use in elite soccer

Test Protocols

The majority of studies which assess all-round fitness in soccer players use a test battery largely consisting of field-based protocols to measure jumping ability, linear speed, agility and aerobic endurance. Several studies using field-based tests are presented in table 2.1, to give an idea of the variety of test protocols in use. Other tests commonly used in mature players are the Yo-Yo intermittent recovery test (Bangsbo 1994b), a range of soccer-specific skills tests, and various measures to evaluate anaerobic endurance, maximal strength and strength endurance. As our test battery will be intended for use in adolescent soccer players, we will only include non-invasive field-based measures, which require inexpensive equipment, are time efficient and therefore are deemed suitable for use in the Scottish youth leagues. Each of the selected protocols are now discussed in detail.

Vertical Jump

The vertical jump test is classically used as an indication of maximal explosive power from the leg-extensor muscles (Davies 1971, Bosco & Komi 1979). Power can be calculated if the mass of the subject, the vertical distance travelled and the flight time are known (Reilly & Doran 2003), but is most accurately measured using a force platform in the laboratory. Less expensive portable electronic devices, which allow measurement in a field setting have been created, which allow jump height to be calculated based on a measure of flight time. Since jump ability has been shown to correlate with team success in elite soccer, it is common practice to use jump height itself as a performance measure.

Various protocols have been used among soccer studies and include the standing start technique or squat jump (SJ) which starts with a 1-3 second pause with knees bent at 90° and hands positioned on the hips, a counter-movement jump (CMJ) which is similar to the SJ but performed as a continuous move from a standing position without the pause at the 90° angle (Arnason et al 2004) and the classic vertical jump (VJ) which uses the technique of the CMJ but with a simultaneous arm-swing to aid in propulsion (Ellis et al 2000). The vertical jump with added arm swing is the most relevant to soccer performance, as players will generally use the arms to aid in balance and in gaining height; the arm-swing component of this jump has been shown to contribute approximately 10% to the jump height (Ellis et al 2000).

In the field-setting, it would be most appropriate to combine both a squat jump protocol to give an isolated estimate of leg power and a counter-movement jump protocol with free arm swing to give a more accurate estimation of jump performance. Mean jump heights of between 50 and 60cm have been reported for professional adult players (Stølen et al 2005), although the jump protocols used for assessment vary. Data is available for a counter-movement jump with free arm swing for Australian youth soccer players reporting values within the range of 47 – 71cm (Tumilty 2000).

Speed (Linear Sprint Ability)

The importance of speed in soccer has been indicated previously and with 89% of UK Premier League clubs performing regular sprint assessments (Erith 2004), this appears to be well accepted. From table 2.1 it can be seen that there is no fixed protocol for measuring speed. Various distances have been investigated ranging from 5m to 40m, with the majority of studies recording sprint time for more than one distance. Each of the studies under review all measure sprint times using infrared photoelectric cell devices, which allow for accurate timing to within 0.01s. Svensson & Durst (2005) found sprint distances of 10, 20 and 30m to be the most popular assessments of soccer sprint ability. Acceleration, as indicated by 10m sprint times is proven to be a relevant measure in soccer, having been shown to distinguishing between amateur and professional players (Cometti et al 2001). According to Stølen et al (2005), 96% of sprint bouts during a soccer game are found to be shorter than 30m so the current literature indicates the distances of 10m and 20m to be the most appropriate.

Stølen et al (2005) reported 15 studies which analysed sprint performance in male soccer players. 10m sprint times ranged from between 1.79 ± 0.09s and 1.90 ± 0.08s for adult players. 20m sprint times ranged from between 3.00 ± 0.15s and 3.31 ± 0.11s for adult players. Data for youth players is limited. Tumilty (2000) reported 10m sprint times of 1.69 – 1.91s, and 20m sprint times of 2.92 – 3.19s for Australian Olympic and National level youth soccer players.

Agility

Agility is the ability to change the direction of the body rapidly and is a result of many neurophysiological factors (Svensson & Durst 2005). The literature suggests that there is currently no agreed upon test for agility measures in use with elite soccer players (Tumilty 2000). The 505-agility test (Draper & Lancaster 1985) has been validated for use among team sports athletes but has yet to be validated for use in a soccer group. The test is used to assess agility in the horizontal plane, and requires participants to approach a line marked out 15-m from the starting point, cross the line, stop and turn to run back 5-m in the same direction. Photoelectric cells are set up to record the time it takes to run the last 5-m of the approach, turn, and run back over the same 5-m. Other tests over longer distances (Illinois agility test and 20m dash) have been shown to be influenced by an individuals' running speed, and therefore agility times favour those individuals who have faster linear running speed (Draper & Lancaster 1985). Ellis et al (2000) advocate the use of the 505 test above other agility protocols, as performance in this test has been shown to be unaffected by an individuals running velocity.

Although the 505-test has not been validated for use in a soccer population, performance standards have been reported for team sports players. Mean values of 2.20s, 2.28s, and 2.25s turning on the right foot and 2.21s, 2.27s, and 2.24s turning on the left foot were found for senior Australian basketball players, hockey players and tennis players respectively (Tumilty 2000). No values have been reported for junior athletes.

Multi-Stage Shuttle Test

The multi-stage shuttle test (MST) is a maximal effort, field-based protocol used to estimate $\dot{V}O_2$ max in groups of athletes. This test is probably the most frequently quoted field measure of aerobic endurance in soccer literature.

The MST is progressive in intensity and involves participant's running back and forth between 2 marked lines spaced 20m apart, in time to pre-recorded audio signals played on a compact disc player. The test is continuous and staged in levels with each level lasting 1-minute; running speed is increased by $0.5km.h^{-1}$ upon reaching each consecutive level. Subjects continue to run until exhaustion, which is indicated by a failure to keep up with the timing of the shuttles. The estimation of $\dot{V}O_2$ max is determined by a retro-extrapolation method (Di Prampero et al 1976, Leger et al 1980), based on measurements obtained through gas analysis at the conclusion of each level of the MST.

The MST has been validated for use in male and female adults on various floor surfaces (Leger & Lambert 1982), male and female adult distance runners (Ramsbottom et al 1988), and female Physical Education students (Ramsbottom et al 1987); correlation coefficients and standard errors of estimated $\dot{V}O_2$ max with directly measured $\dot{V}O_2$ max were found to be; r = 0.84 and SEE = 5.4ml.kg-1.min-1, r = 0.92 and SEE = 3.5ml.kg-1.min-1, and r = 0.92 and SEE = 3.5ml.kg-1.min for each study respectively. Leger et al (1988) studied the test responses of young schoolchildren aged 6 – 16 years and found the test to be both a valid estimate of $\dot{V}O_2$ max ($r = 0.90$) and reliable in terms of test-retest reliability ($r = 0.89$).

Although the use of the MST for estimation of $\dot{V}O_2$ max has been validated, the predictions of $\dot{V}O_2$ max can be overestimated or underestimated by up to 3.5ml.kg^{-1}.min^{-1}. Soccer professionals therefore recommend that endurance performance be expressed as a total distance ran rather than estimated $\dot{V}O_2$ max to eliminate the error in conversions. Therefore our reproducibility estimates will only focus on the actual MST performance, measured as the total distance (m) ran during the test.

Not many studies report MST performance in the form of the total distance covered. However many of the estimates of $\dot{V}O_2$ max available for elite soccer players have been derived from MST performance. The corresponding MST levels for the expected elite adult standard of $\dot{V}O_2$ max (60 – 70ml.kg^{-1}.min^{-1}) are approximately Level 13 (shuttle 13) – Level 16 (shuttle 12) which equates to a distance of between 2580m – 3340m. Mean levels for youth players have been reported as level 12 (shuttle 12) for Australian under 17 players and level 13 (shuttle 9) for Australian Olympic youth players which can be converted to the distances of 2320m and 2500m (Tumilty 2000). No values have been found for younger players.

2.7 Research Proposal

The previous review has highlighted the importance of physiological fitness to soccer success. Several essential fitness components have been identified and the current methods of choice for the assessment of each fitness parameter among professional football clubs have been discussed. In light of the financial shortcomings at most Scottish football clubs, the introduction of regular performance assessment to the players in the youth development squads is likely to be limited to simple field-based protocols. The protocols considered to be appropriate for our investigation include: squat jump, counter-movement jump, 10 and 20m sprint times, 505-Agility test and multi-stage shuttle test.

3 Methods

3.1 Subject Information and Experimental Design

A total of 76 young male soccer players volunteered to take part in the study. All were active participants in a professional youth football league and took part in a minimum of 3 x 90-minute, moderate-high intensity training sessions per week. Subjects were recruited from the youth development squads of 2 Scottish Premier League football clubs. Mean (± sd) for age, height, and body mass were 13.2 ± 1.4 (y), 1.59 ± 0.12 (m), 47.9 ± 11.3 (kg).

Consent

The study was approved by the ethics committee for the Institute of Biomedical and Life Sciences at the University of Glasgow. Written consent was obtained prior to testing; consent was obtained from a parent or guardian as all subjects were under the age of 18. All potential subjects were given an information pack which included a detailed information sheet (Appendix 1), and a medical questionnaire with parental consent form (Appendix 2). Subjects and parents were informed that participation was not obligatory and that involvement in the study was on a voluntary basis only. It was also highlighted that withdrawal from the study was possible at any time without penalty or detriment to any future relationship with the football clubs.

Safety

Subjects were approved to take part in the study if they were considered to be in good health, with no conflicting medical conditions or injuries (as detailed in the medical questionnaire), and were found to have a blood pressure reading no higher than 160mmHg (systolic) and 95mmHg (diastolic). Subjects were screened for changes in health status prior to each testing session and excluded from participation if they showed any signs of illness or muscle/joint injury within the previous 48-hours.

Due to the cardiovascular risks involved in maximal tests of aerobic power, it was stipulated that at least one member of the research team, trained in basic life support and defibrillation techniques, be present during the testing sessions alongside one other adult who was fully trained in first aid. A semi-automated defibrillator, oxygen cylinder (100% oxygen), self-inflating resuscitation bag with reservoir, facemasks (2 sizes) and suction connection, were also present at each session. A first-aid box was available to deal with any minor incidents.

Design

Subjects took part in a field-based test battery consisting of protocols to evaluate each of the following components of fitness: Jump Ability (Squat Jump & Counter-Movement Jump), Maximum Linear Speed (10m & 20m sprint times), Soccer-specific Agility (505-Agility test), and Aerobic Endurance (Multi-stage Shuttle Test). Each of the test protocols are described in chapter 3.3 following the guidelines detailed by the Australian Sports Commission (Tumilty 2000).

In order to determine the reproducibility of each test, subjects were asked to completed the test battery on 2 separate occasions; test 1 to gain initial scores and test 2 as a replicate measure taken exactly 14 days later. Test conditions were controlled, i.e. took place in the same location, at the same time of day, and following the exact same protocols for set-up and implementation as detailed in chapters 3.2 & 3.3. Training sessions over the 14 day period between tests were pre-arranged to keep activity levels constant and ensure that subjects had a rest day prior to testing. It was suggested that subjects keep a food diary which would help them to maintain similar dietary and hydration habits during the 48-hour period before testing. Subjects were blinded to the exact nature of the investigation, in an attempt to avoid any bias affecting performance. No details were provided regarding test performance until after the study was complete.

Familiarisation

It was agreed that subjects should have taken part in each of the tests involved in the study on a minimum of 2 occasions, in order to be adequately prepared for the test sessions. Several subjects had previously been assessed using the exact protocols involved in the test battery, as part of the normal training programme implemented at their football club, on at least 2 previous occasions. It was considered that these subjects would therefore require no further familiarisation and were given the option not to attend the familiarisation sessions. All other subjects were taken through 2 separate familiarisation sessions over the 2 week period prior to testing; session 1 occurring 14 days before testing, and session 2 occurring 7 days before testing.

On both occasions, the familiarisation session was carried out in a group setting in the actual testing environment. All equipment was set-up as it was for the actual testing sessions (see chapter 3.2). A detailed explanation was given covering exactly what each test would involve, and subjects were given the opportunity to explore the test environment and familiarise themselves with the set-up. Each piece of test equipment was explained to the subjects, who were then given a demonstration of the actual test technique.

Subjects were then taken through a 10-minute warm-up under the direction of the team coach. Immediately following the warm-up, subjects performed the test battery as described in chapter 3.3, with the exception that no actual scores were recorded at this stage in the study. Due to time constraints, subjects were only required to take part in the first 4 levels of the MST during the familiarisation sessions.

Testing Sessions

Subjects were tested in 6 groups of 9 – 15 players with the test sessions taking place in one of two indoor sports halls. Due to unavoidable logistical problems, different equipment was available at each location but where possible the same make and model of equipment was used. (See table 3.1 for details of equipment used).

Not all subjects took part in both test 1 and test 2 of each test measure; this was unavoidable due to factors such as injuries, match commitments or personal choice. A summary table of subject numbers for each test is provided in table 3.2.

	Location A	Location B
Jump Tests	Contact Mattress (Just Jump, Probotics, USA)	Contact Mattress (Just Jump, Probotics, USA)
Sprint Tests	Electronic Photocell Timing Gates (Newtest Power Timing System, Finland)	Electronic Photocell Timing Gates. (Brower Timing System, England)

Table 3.1 Details of equipment used

	Subject Numbers
Squat Jump (SJ)	68
Counter-movement Jump (CMJ)	68
10 m Sprint Time (10m)	76
20 m Sprint Time (20m)	76
Agility – Right Turn (505-R)	75
Agility – Left Turn (505-L)	74
Multi-stage Shuttle Test (MST)	68

Table 3.2 Summary of subject numbers for each test protocol

Anthropometry & Blood Pressure

Prior to the actual test date, subjects were given individual appointments to attend a meeting at their football club with the research team and a member of the clubs coaching staff. Parents were encouraged to attend the meeting to allow an opportunity for any questions to be answered. The meeting was used to review the relevant paperwork and obtain measures of blood pressure, height and body mass.

Upon arrival to the test location, both the medical questionnaire and consent form were collected. Stretch stature was recorded in metres rounded to the nearest centimetre using anthropometric tape (Lufkin, Mexico), with the subjected standing bare-foot against a wall, as described by ISAK (2000). Body mass was recorded in kilograms rounded to the nearest hundred grams using electronic scales (Tanita TBF-551, Japan) with subjects wearing only light football shorts. Blood pressure was recorded using a sphygmomanometer (Body Care, England); 3 readings were taken and the average was calculated. At this point, any subject who was not considered eligible was released from participation.

3.2 Preparation & Set-Up

Prior to each test session, the following safety equipment was checked and found to be in working order.

- A semi-automated defibrillator
- Oxygen cylinder (100% oxygen)
- Self-inflating resuscitation bag with reservoir, facemasks (2 sizes) and suction connection
- First-aid Kit

All safety equipment was present at each test session, accompanied by at least one member of staff trained in the use of the equipment.

The following equipment was also checked and found to be in working order.

- Contact Mattress and Display Unit
- Sprint Timing System including 3 pairs of photocells, 3 tripods and monitor
- Compact Disc Player and 2 copies of the MST compact disc

Other equipment required included 20 marker cones, a wooden bench and an exercise mat. Spare batteries for each piece of equipment were also required.

Hall Set-up

The sports hall was marked out with clearly visible taped lines at 0m, 10m, 15m and 20m distances. The lines were marked across the width of the hall and positioned so that a start line for the sprint tests could be marked out 0.75m behind the 0m line, and a clear distance of at least 20m was available beyond the 20m line to allow ample space for subjects to slow down after the sprints. A sprint lane was set-up using the timing gates. A timing gate consists of 2 cells, 1 emitting an infra-red beam and the other a photocell which acts to receive the beam. The cells are fixed in place on top of tripods. In assessments of linear speed, 2 or more beams are required to make a complete timing system. The timing system is linked to a hand-held monitor that displays the timing information. When a person runs through the gate, the breaking of the beam starts the timer on the monitor; the timer continues to run until the beam is broken at the next timing gate.

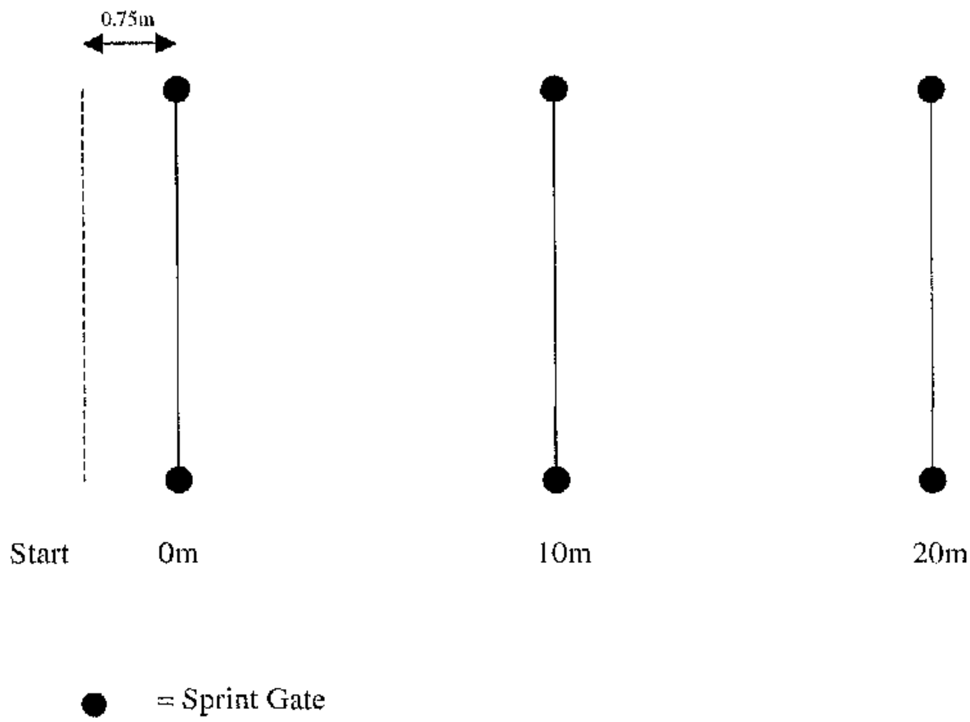


Figure 3.1Illustration of sprint protocol set-up

Photocells were placed at 0m, 10m and 20m distances in preparation for the sprint tests (Figure 3.1). To ensure the correct positioning of the cells, one tripod leg was set on the appropriate taped line, with the other 2 legs positioned either side of the line. The position of each leg was clearly marked as a reference point to ensure the same set-up was used for subsequent test sessions. The cells were fitted with the tripod legs set at a height of 1metre and the cells spaced 1.5 metres apart. A plumb-line was used to check the distance between cells and ensure that the beam was set straight along the length of the marked line.

The jump mat was set out in an area separate from the sprint lane, and the marker cones and the compact disc player required for the MST were stored in a separate area until required during the test session.

3.3 Test Protocols

Pre-warm up Instruction

Upon arrival at the test location, subjects were questioned on any recent injuries or illness, and advised whether to participate in the session. Care was taken at this time to stress to the subjects that they may drop out of the testing at any time should they not wish to continue. They were advised that they must do so should they start to feel unwell. Where available, subjects were supplied with a heart rate monitor and watch (Polar A1, Finland), and assisted in putting on the chest strap securely. (Unfortunately this equipment was not available at both locations).

Warm Up 1

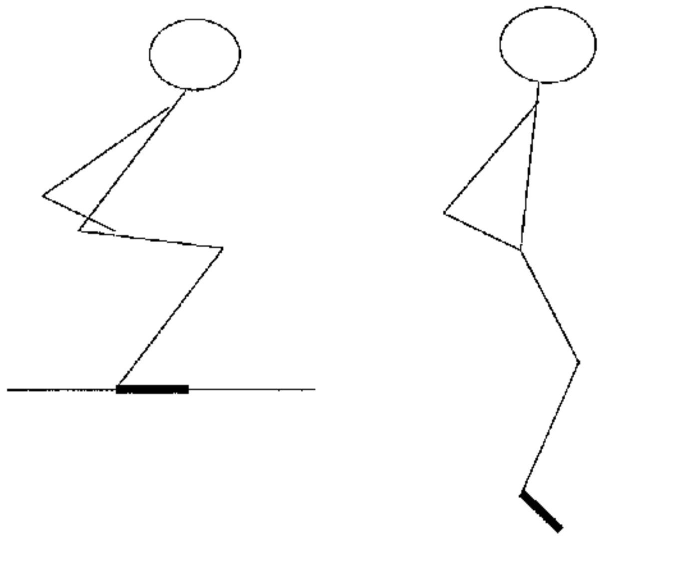
All subjects performed a 5-minute group warm-up session, under the instruction of the team coach. The session was of progressive intensity, and consisted of continuous, multi-joint agility and dynamic flexibility movements.

Jump Tests

All jumps were performed on an electronic contact mattress. Jump height (m) was displayed on a hand held monitor attached to the mattress by a cable. Subjects were organised in alphabetical order of surname, in a queue behind the jump mattress and advised to keep active by jogging and performing similar continuous movements in between jumps. Subjects were called forward by name to perform each individual jump and then asked to rejoin the end of the queue to await the next jump. A stopwatch was used to ensure subjects had a minimum recovery time of 1 minute between each consecutive attempt. 2 types of jump were assessed; the squat jump (SJ) and the counter-movement jump (CMJ) and subjects performed 12 jumps in total (6 SJ and 6 CMJ).

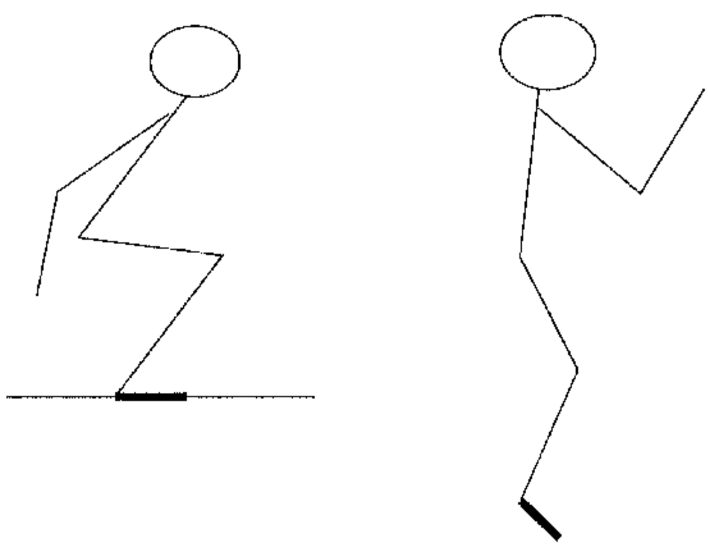
Squat Jump

The SJ (see figure 3.2) was performed with the hands positioned on the hips, to prevent any assistance from the upper-body in gaining height. Subjects were instructed to start by standing on the contact mat with feet positioned hip-width apart, and knees bent to a



Start – held for 3 secs Jump – hands stay fixed

Figure 3.2 Illustration of Squat Jump Protocol



Start - arms free Jump – with arm swing

Figure 3.3Illustration of Counter-movement Jump Protocol

90°angle with heels firmly on the ground. The hands were then positioned on either side of the hip and subjects were instructed to look forward and keep their head up straight. Once in the correct stance, subjects' held the position and counted out loud to 3, and then jumped upwards as high as possible without removing the hands from the hips. The subjects were instructed not to lift their knees or feet out in front of them during the jump and to land with feet in as near to the same position on the mat, as they were at take-off. The knees were softened on landing to absorb the impact. Each subject performed 6 jumps; the first 3 attempts were sub-maximal and intended as practice jumps. Scores for the practice jumps were not recorded. When reaching the fourth attempt, subjects were then asked to perform the remaining 3 jumps at maximum effort, keeping the correct technique whilst aiming to jump as high as possible. The 3 maximal jump heights for each subject were recorded in metres to the nearest centimetre, and the best score was used for the statistical analysis.

Counter-movement Jump

The CMJ (see figure 3.3) was performed with the aid of an arm-swing to help propel the subject into the air. Subjects started standing upright on the mat with feet placed hip-width apart and arms relaxed by their side. In one continuous movement, the subject then performed a downward counter-movement by bending the knees and reaching the arms behind, before immediately reversing the action and jumping up into the air, simultaneously swinging the arms upwards to aid in propulsion. No forward lift of the feet or knees was allowed during the jump. The subject landed with feet in as near to the same position as they were in take-off with a slight bend at the knee to soften the landing. Again, subjects performed 3 practice jumps and 3 maximum effort jumps, each with a minimum of 1-minute rest in between. The 3 maximal CMJ heights were recorded in metres to the nearest centimetre and the best score used for the statistical analysis.

Warm up 2

To ensure that the players were adequately warmed up before moving on to the next part of the test session, players were taken through another group warm up session. This followed the exact same procedures as described for warm up 1, but this time over a 10-minute period.

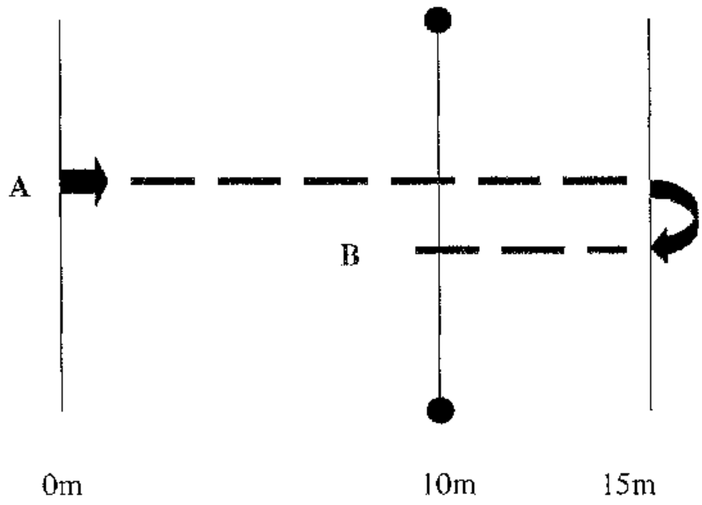
Sprint Tests

The subjects were organised in their alphabetical queue at the side of the sprint lane and advised to keep active by jogging in their place whilst waiting to be called forward in turn for each run. When called forward and awaiting the instruction to 'go', subjects were asked to maintain an upright position with both feet behind the designated start line. When the timer had been reset, the experimenter gave the commands 'ready' and 'go'. Subjects then ran between the gates and continued to sprint as fast as possible over the marked 20m line before slowing down. Upon completion of each sprint, subjects were instructed to jog back to the end of the queue and continue to keep active whilst waiting on their next run.

Each subject performed 3 progressive warm-up sprints, carried out at approximately 50, 70, and 90% of maximum speed. After all had completed 3 practice runs, the gates were activated and subjects instructed that the next 3 sprints were to be performed at maximum speed. A 2-minute recovery period was timed after the last subject in the group had completed each sprint. As the runs were performed in a queuing system, this ensured that each player had a minimum of 3 minutes rest between each consecutive sprint. This recovery period was considered adequate for regeneration of phosphocreatine levels as suggested by Boobis et al (1982), and Holmyard et al (1988). The 3 maximal sprint times at 10m and 20m distances were recorded in seconds to the nearest hundredth of a second, and the fastest time over each distance used for the statistical analysis. Upon completion of the sprint test, subjects were given a 5-minute timed break to re-hydrate.

505-Agility Test

During the 5-minute break, the timing gates were removed from the 0m and 20m lines leaving only the 10m line timing gate active for the agility measures. The players were instructed to start at the marked 0m line and run to the 15m line. As the subject crossed the 10m line the timing gate was activated. Immediately upon reaching the 15m line the subject had to put one foot over the line and turn to run back through the timing gate to stop the timer as illustrated in figure 3.4. Players were instructed that at least one foot must cross the 0m line, or the run would not be accepted. An experimenter was positioned alongside the 15m line to ensure each subject crossed the line, if a subject stopped short of the line then another run had to be completed at the end of the test. Players queued and kept active in the same manner as the sprint tests above and again waited for the 'ready' and 'go' commands before starting to run.



A = Start, B = End.

Figure 3.4 Illustration of 505-agility test with left foot turn

The practice runs consisted of a total of 4 sprints progressing through approximately 50, and 90% of maximum intensity; alternating turns to the left and right. In order to avoid any bias, the first player to run was instructed to start with a left turn, and the next player instructed to start with a right turn (this pattern of alternation was continued for the entire group).

After the practice runs, the speed gates were activated, and each subject performed 4 maximum sprints alternating turns, as instructed, to the left and the right. A 2-minute recovery period was timed after the last subject in the group had completed each sprint. As the runs were performed in a queuing system, this ensured that each player had a minimum of 3 minutes rest between each consecutive sprint. Sprint times for the 4 maximal runs were recorded in seconds to the nearest hundredth of a second. The fastest time with a left turn and the fastest time with a right turn were used for the statistical analysis.

After the last runner had completed the agility test, the clock was set for a full 5-minute recovery period before the subjects took part in the multi-stage shuttle test. Subjects were encouraged to keep warm and re-hydrate throughout this period.

Multi-stage Shuttle Test (MST)

During the 5-minute recovery period, the last timing gate was removed and lanes were set out with the marker cones along the 0m and 20m lines. Each cone was spaced 1 metre apart to provide 9 lanes for the MST. The compact Disc player was positioned at the side of the lane set-up on a wooden bench. Subjects were tested in groups of 5 – 9 players depending on the number of subjects in their group. Before starting the tests, the players listened to the pre-test instructions on the disc and were given the opportunity to walk through the first level of the test. At this point the volume of the CD player was checked to ensure all subjects could clearly hear the bleeps. The instructions stated that subjects must put one foot over the line in time with each bleep, and should they reach the line after the bleep on 3 consecutive occasions they would immediately be dropped from the test. Subjects were encouraged to run for as long as they could. Again it was stressed to subjects that they could drop out of the test at any time and that they must stop if they began to feel unwell. The subjects were further advised that they must not suddenly stop or sit-down when they dropped out of the test, but that they should continue to jog/walk and slow down gradually until they were no longer struggling for breath.

As subjects dropped out of the test, those with heart rate monitors were immediately approached by a member of the research team who recorded the peak heart rate displayed on the subjects watch.

Warm down

Once all subjects had finished and recovered from the MST a group warm-down session was conducted. This involved 5 minutes continuous movement gradually decreasing in intensity from jog - walk pace. Players were encouraged to re-hydrate throughout. All subjects were asked if they felt well after the tests before being allowed to leave.

3.4 Statistical Analysis

The Minitab Statistical Software Package (Minitab Release 14) was used for all of the data analysis procedures. Unfortunately there were too few subjects in each age group to perform separate squad analyses as was originally intended; therefore all subjects were combined into a single group to increase statistical power.

A simple comparative analysis was carried out using paired t-tests to determine any systematic bias between test 1 and test 2 scores for each of the test protocols. Where no significant differences were detected ($p = >0.05$), the standard deviations (SD) of the differences were used to calculate the 95% limits of agreement using the methods of Bland & Altman (1986); a summary table of statistics is provided. The limits of agreement are used to quantify the random error expected in repeat measures, and are defined as ±0.96 * SD of the mean difference between the repeat measures. For example, if the mean difference between test 1 and test 2 in the squat jump was 0.00m with a standard deviation of 0.01m, then the LOA would be equal to ± 0.02m; suggesting that a change in jump height of 0.02m or less is likely to be due to random biological or mechanical error rather than a change in jump ability.

Finally the between tests differences, and where appropriate, the limits of agreement are illustrated using Bland and Altman plots with the data points colour co-ordinated to represent each of the squads (U11s – U17s) in an attempt to identify any possible trends in measurement error between the squads.

4 Results

		Test 1	Test 2	+ Difference	*LOA
Subjects = 68	**SJ (m)**			p = 0.17	±0.06
	Mean	0.40	0.39	0.01	
	SD	0.05	0.06	0.03	
	Range	(0.29, 0.52)	(0.28, 0.55)	(-0.00, 0.01)	
Subjects = 68	**CMJ (m)**			p=0.542	±0.06
	Mean	0.47	0.46	0.00	
	SD	0.06	0.05	0.03	
	Range	(0.34, 0.62)	(0.34, 0.67)	(-0.01, 0.01)	
Subjects =76	**10m (sec)**			p=0.000	
	Mean	1.87	1.90	-0.03	
	SD	0.11	0.11	0.06	
	Range	(1.62, 2.14)	(1.67, 2.15)	(-0.05, -0.02)	
Subjects = 76	**20m (sec)**			p=0.000	
	Mean	3.32	3.37	-0.06	
	SD	0.22	0.22	0.09	
	Range	(2.86, 3.71)	(2.92, 3.94)	(-0.08, -0.04)	
Subjects = 74	**505-L (sec)**			p=0.966	±0.32
	Mean	2.64	2.64	0.00	
	SD	0.2	0.16	0.16	
	Range	(2.30, 3.53)	(2.35, 3.04)	(-0.04, 0.00)	
Subjects = 75	**505-R (sec)**			p=0.75	±0.26
	Mean	2.62	2.62	0.00	
	SD	0.17	0.16	0.13	
	Range	(2.31, 3.01)	(2.28, 2.92)	(-0.03, 0.03)	
Subjects = 68	**MST (m)**			p=0.034	
	Mean	1764.71	1824.12	-59.4118	
	SD	296.19	342.07	226.14	
	Range	(1020, 2620)	(1040, 2600)	(-114.15, -4.67)	
+ Difference = test1 - test 2 (p <0.05 = significantly different) SD = Standard Deviation					
* Limits of agreement calculated using the formula ± (1.96*SD of Difference)					

Table 4.1 Descriptive statistics from test 1 and test 2 data comparisons

The results from the paired t-tests reveal no significant differences (p=>0.05) between test 1 and test 2 scores for the squat jump, counter-movement jump and 505-agility runs. Both the 10m and 20m sprint tests show a systematic bias towards running slower in test 2, whilst the multi-stage shuttle test was biased towards a better performance in test 2.

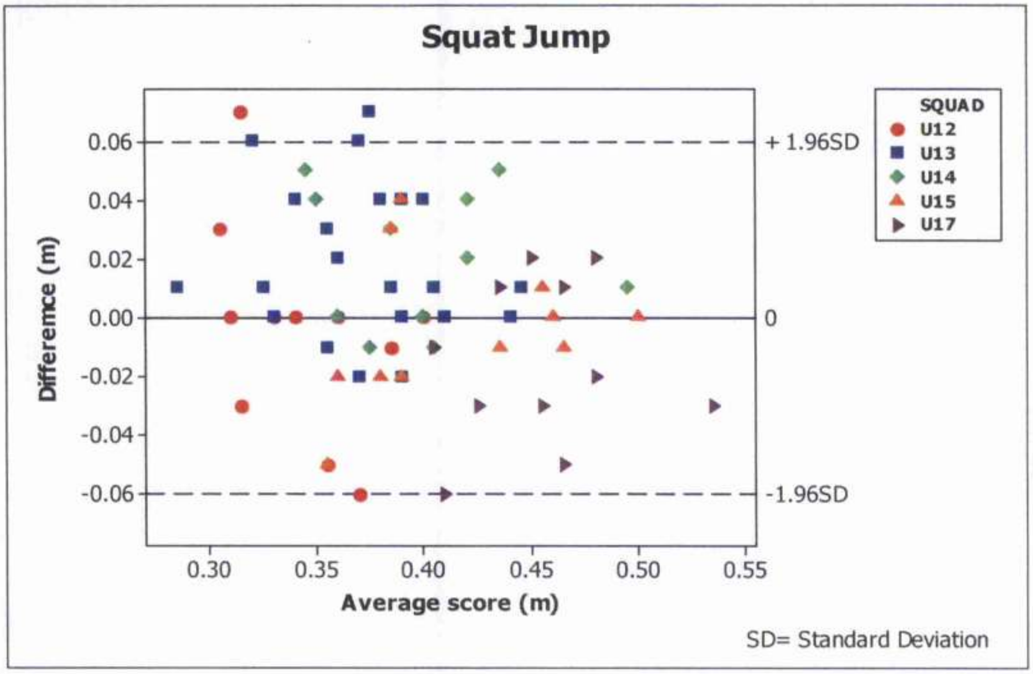


Figure 4.1 Bland & Altman plot for SJ data

The 95% limits of agreement indicate an expected measurement error of ±0.06m in repeat measures of both the SJ (Fig 4.1) and CMJ (Fig 4.2). There are no obvious trends in measurement error apparent between the squads for either jump protocol, although the majority of U14 players appear to perform better in test 1 of the squat jump and the majority of U17 players performed better in test 2 of the same protocol.

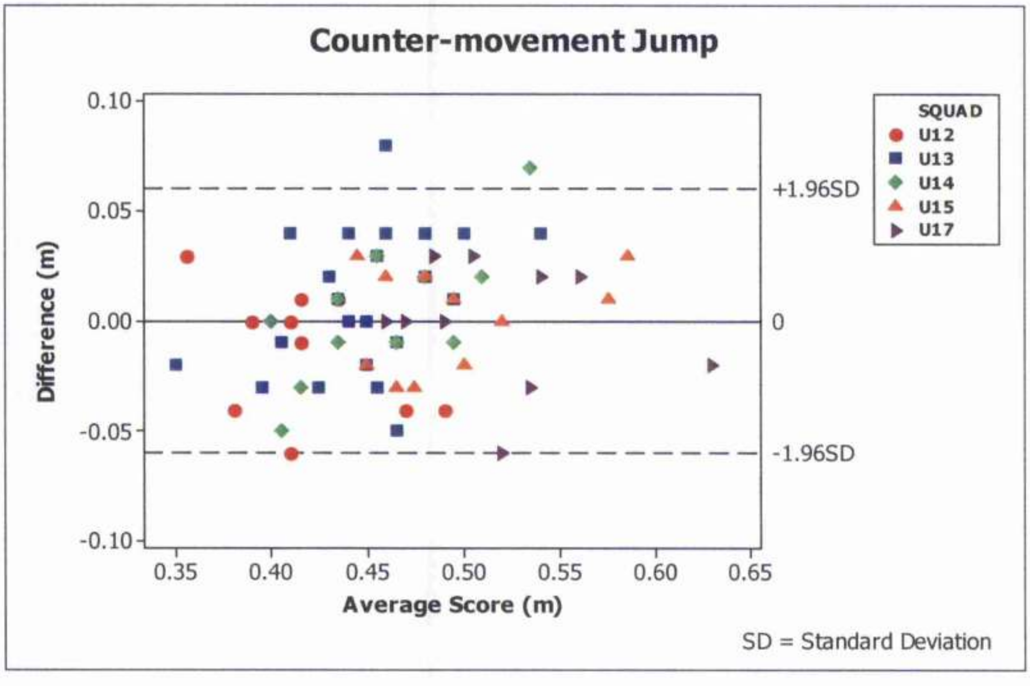


Figure 4.2 Bland & Altman plot for CMJ data

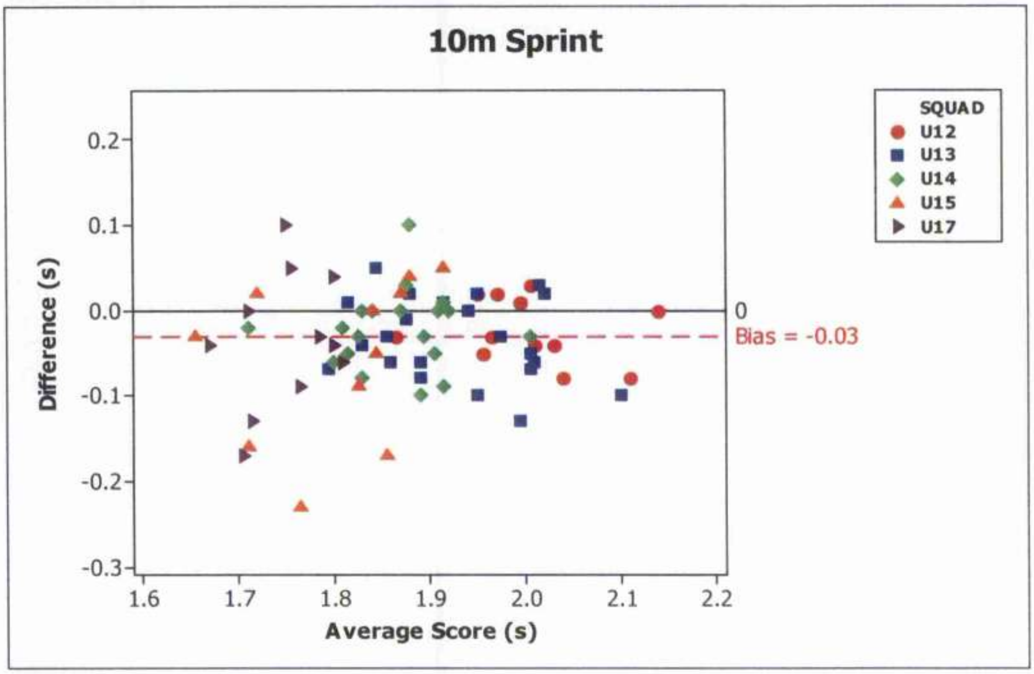


Figure 4.3 Bland & Altman plot for 10m sprint data

The systematic bias between test 1 and test 2 scores for both the 10m and 20m sprint protocols can be seen in the figures below with the majority of the data plots lying below the zero difference reference lines. The mean bias is illustrated by the red reference lines in figure 4.3 (10m) and figure 4.4 (20m). There are no obvious squad trends in measurement error.

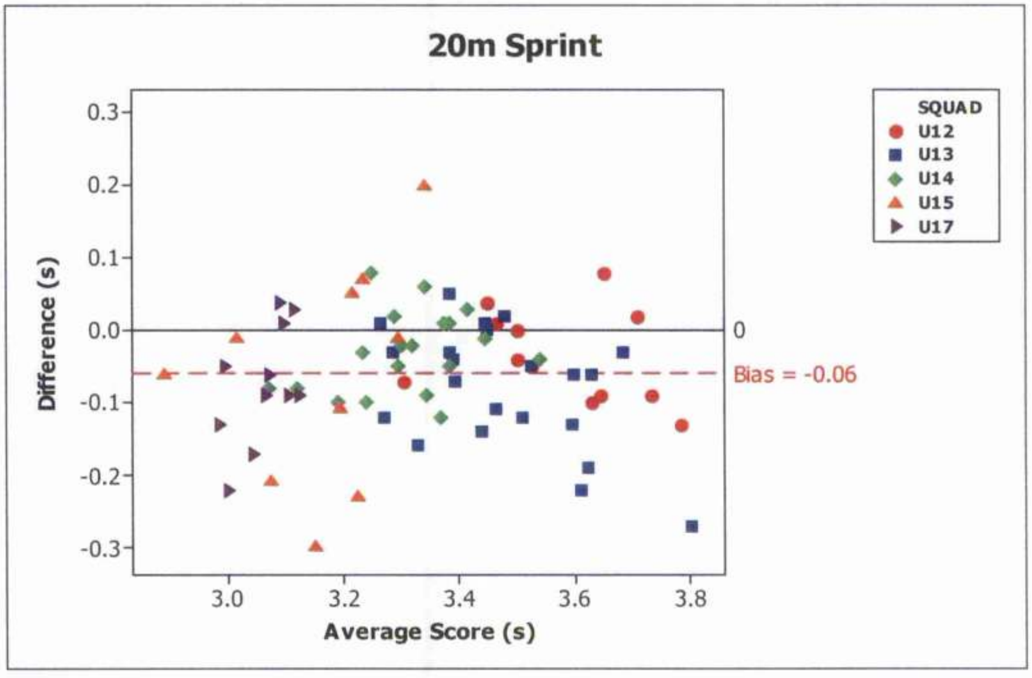


Figure 4.4 Bland & Altman plot for 20m sprint data

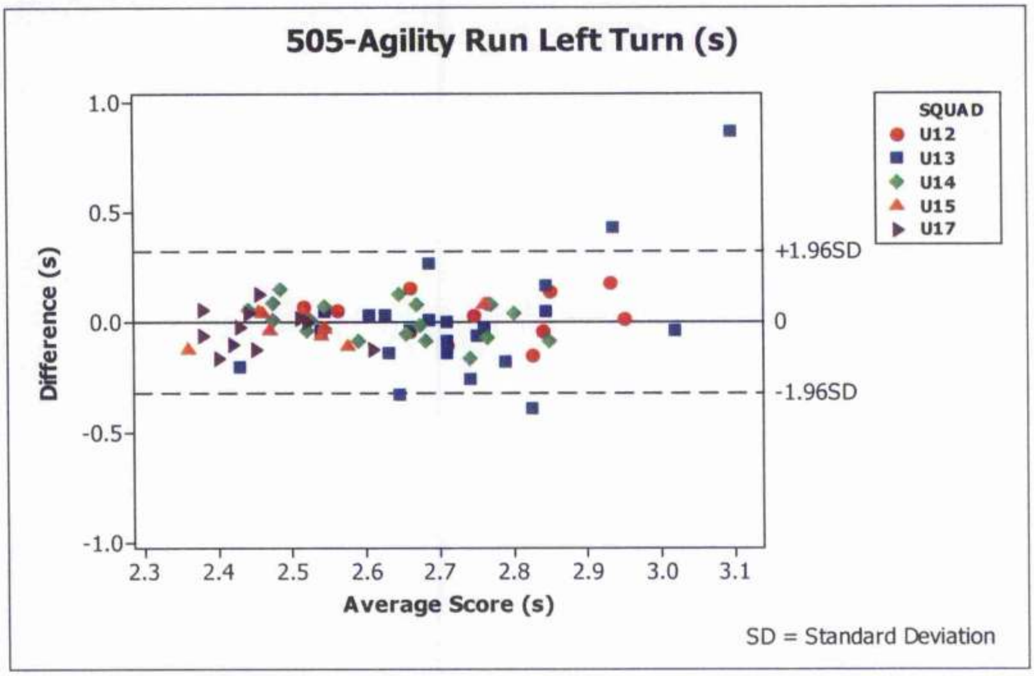


Figure 4.5 Bland & Altman plot for 505-agility run (left turn) data

The differences between test 1 and test 2 appear to be evenly spread between the squads for both the left and right turn of the 505-agility tests, with the exception of a few outlying subjects from the U13s squad as seen in figure 4.5. The expected measurement error was calculated to ±0.032s (left turn) and ±0.026s (right turn).

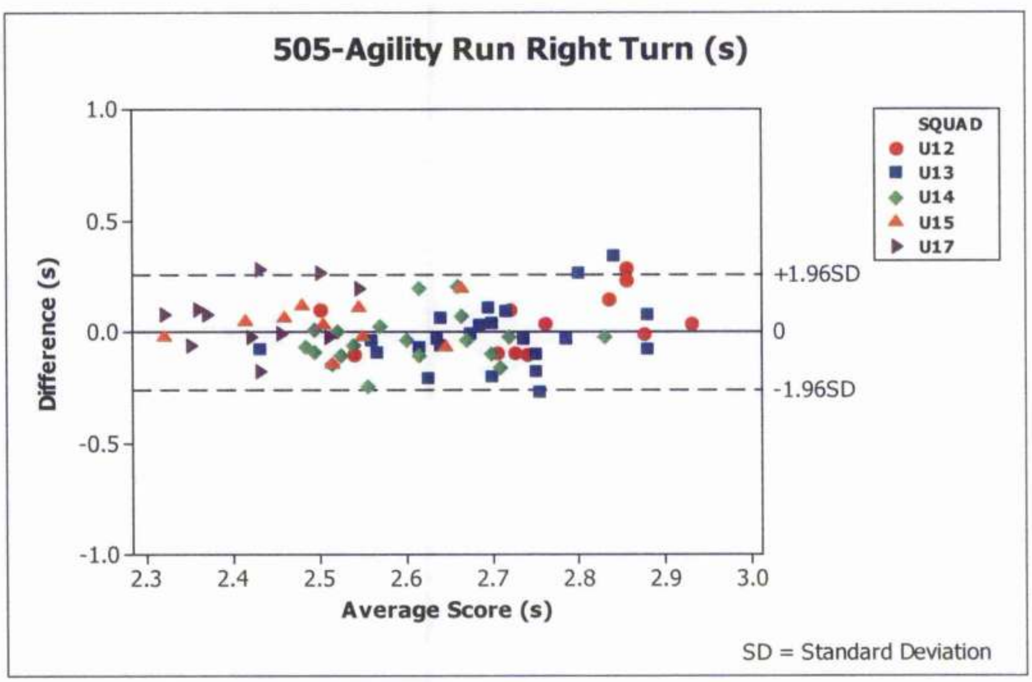


Figure 4.6 Bland & Altman plot for 505-agility run (right turn) data

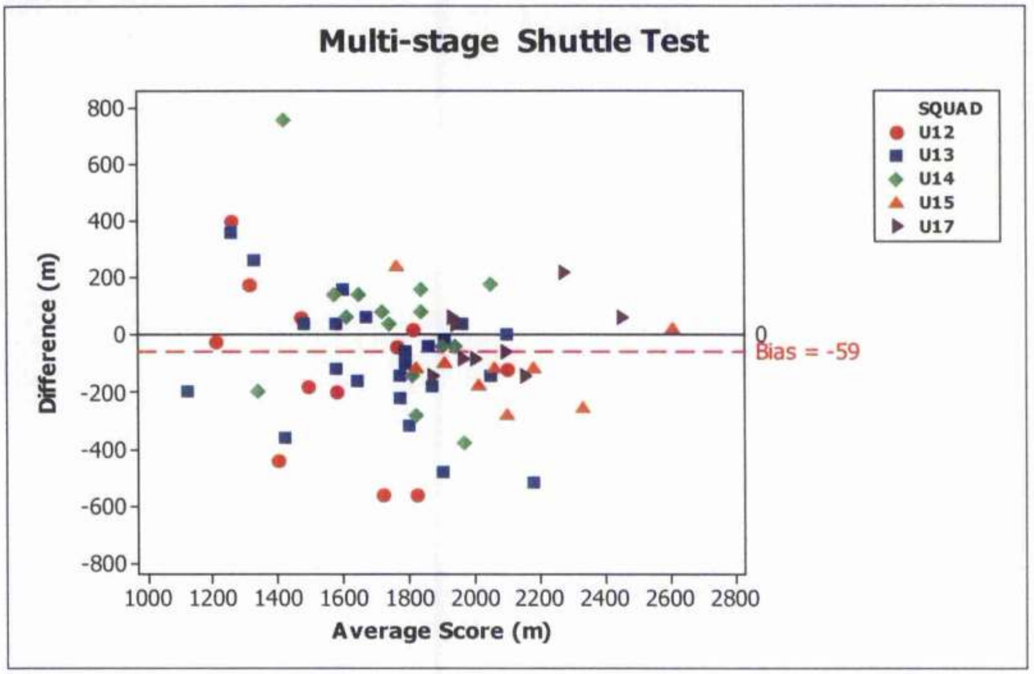


Figure 4.7 Bland & Altman plot for MST data

The systematic bias found between test 1 and test 2 of the MST can be seen in figure 4.7 with the majority of the data plots lying below the zero difference reference line. The mean bias is illustrated by the red reference line showing a mean difference of -59m. The range of between test differences appears to be less widely spread in the U17's squad than in the younger groups.

5 Discussion

5.1 Jump Tests

The between-test differences for the Squat Jump (SJ) and Counter-movement Jump (CMJ) were found to follow a normal distribution with no systematic bias evident between scores for either jump protocol. Therefore, in our investigation it appears that both the SJ and CMJ protocols were reproducible. As stated in the literature review, few publications have been found which report reproducibility or reliability for soccer-specific test protocols. Furthermore, comparing our findings to the few relevant publications located is difficult due to variations in the statistical methods adopted. Arnason et al (2004) reported reliability for a standing jump protocol (equivalent protocol of the SJ protocol) calculated as a coefficient of variation (CV), which is generally calculated based on the average measurement of the sample data. As a result, its use as a tool for assessing measurement error in investigations of human performance has received criticism, since the degree of repeat-measure agreement for an individual will depend on the magnitude of the measured value (Atkinson & Nevill 1998); in other words, the CV method assumes non-constant variance and that the higher the score, the greater the between test variation. The actual degree of variance in our study has been quantified using the limits of agreement method which assumes constant variance regardless of the measurement value.

Limits of agreement

The Bland & Altman limits of agreement indicate an expected variance of ±0.06m in a repeat measure of both the squat jump and counter-movement jump protocols. This suggests that in periodic assessments of jump performance, changes in test score lying within these ranges would most likely reflect the normal day-to-day variance seen within this subject group. In order to be confident that a player had improved his jump ability, an increase in score of greater than 0.06m would be required. Considering that the average scores from our study were 0.40m (SJ) and 0.47m (CMJ), this means that our hypothetical average player would be required to improve his jump performance by a minimum magnitude of 15% (SJ) and 13% (CMJ) before we could be confident of a meaningful change in performance.

When using the test protocol to assess the effectiveness of a training intervention, even small gains in jump height would be considered beneficial to performance. Therefore the test protocol does not seem suitable for this purpose. A similar reliability study carried out on 18 professional youth players also found broad limits of agreement when assessing leg power by jump performance. Hood et al (2002) calculated the limits of agreement to be between -6.8cm and +8.9cm in repeat measures of a standing vertical jump protocol. The authors concluded that due to the high variance present in the retest values, the test administration required further work before it could be considered reliable for future use.

Based on our findings it appears that the squat jump and counter-movement jump protocols, as currently administered, are accompanied by high levels of measurement error. As the variance in a repeat measure is quite substantial, the test lacks the sensitivity to be used as a tool for evaluating small changes in performance. Whether the protocol is appropriate for further use will ultimately depend on the analytical goals of the coach/sports scientist and the degree of change desired. Our conclusions agree with that of Hoff (2005), who recently suggested that test mats, which calculate jump height from flight time, have a higher variation than is desirable, but that the method can still be useful when more accurate measures are unavailable, as long as the limitations are understood.

5.2 Sprint Tests

Test Bias

The statistical analysis established the presence of a systematic bias between test 1 and test 2 for both the 10m and 20m sprint tests; with the majority of players running faster in test 1 than test 2. Therefore the sprint protocols were not found to be reproducible in this investigation. Atkinson and Nevill (1998) and Hopkins (2000) proposed several factors that may result in a systematic bias during repeat measure analyses;

- Insufficient recovery from previous activity.
- Training or learning effects.
- Transient swings in motivation.

Insufficient recovery from training or matches is unlikely to be the cause of the bias in this study as the pre-test activity and training loads were controlled; additionally if fatigue were responsible, we would expect to see the same bias for the other power-based tests i.e. the jump tests and agility runs. If the bias was due to either a learning effect or a training effect then we would have expected the players to perform better in the second test rather than the first. It is possible that the bias may be in some way a reflection of motivational factors. Although efforts were made to maximise player motivation in both test sessions it is possible that motivations were higher in the first session due to the excitement and novelty of taking part in the study.

A similar study by Hood et al (2002) assessed the reproducibility of a battery of fitness tests which included 3 sprint test protocols: a 10m sprint from a standing start, a 10m sprint from a flying start, and a 30m sprint from a standing start. The 10m sprint test initiated from a standing start was deemed unreliable due to a high typical percentage error. However, the 10m sprint protocol initiated with a flying start was found to be reliable; with limits of agreement reported to be (-0.04, +0.05s). The 30m sprint from a standing start was also found to be reliable, with limits of agreement of (-0.11, +0.27s). These findings indicate that reliability is likely to be influenced by how the subjects start the 10m sprint. Svensson and Durst (2005) suggest that a more realistic representation of sprint performance will be obtained if players perform a sprint from a flying start (walk, jog or a stride) rather than a static standing start. This method would be more realistic to the game situation as most accelerations on-field will begin when the player is already in motion. If the players are unaccustomed to delivering maximum acceleration from a static position then this would introduce the potential for greater variability in sprint times. Such variability would be less likely to affect sprints over longer distances i.e. 20m or 30m as the players have more time to reach maximum velocity. It is possible that a longer period of familiarisation may have helped the players to perform the sprints with a more consistent technique. However, as a good field-based performance test should closely reflect the demands of the sport, it may be more appropriate to alter the standing start method of the protocol to a flying start. Further investigation is recommended to determine whether a flying start would produce less variance.

5.3 Agility Tests

The results from the paired t-test found no significant difference between test 1 and test 2 scores for the agility run protocols. However, unsuitably high test re-test variability is evident upon examination of the Bland & Altman limits of agreement, which were equivalent to approximately ±0.30s for both the right and left turns. Such variability equates to approximately 11% of the mean agility score for the group.

Observations

The high variance observed for the agility scores may be a result of collecting insufficient data. Only 4 agility times were recorded for each subject, which were 2 attempts for each direction of turn. Only the best times for each foot were used in the statistical analysis. For many subjects, the difference between the best time and the additional attempt (not used for analysis) was quite significant (up to 0.42s) and with such limited data there is no way to be sure of whether a subject had performed to the best of his ability in both sessions. As the agility runs took place after the subjects had conducted numerous sprint tests, it is also possible that the subjects may have lost interest and failed to put in a maximum effort.

In future it would be better practice to ensure a minimum of 3 attempts for each direction of turn. Recording 3 attempts would be more informative than 2, as we would then be able to detect unusual results. The results could be checked after the 3 attempts for variability, and if the difference between the 2 best attempts for any one subject was found to be greater than 0.30 seconds (suggestion based on the calculated 95% limit of agreement), an additional attempt would be required. Ensuring such consistency in test performance would help prevent inaccurate results due to poor measurement technique. It may also be appropriate to conduct the agility tests on a separate occasion to remove any chance of repetition having a negative effect on motivations. Further investigation of reproducibility with the revised protocol would then be required.

Based on the test re-test data collected, we conclude that the 505-agility test as administered in this study is an unreliable method for assessing agility performance in youth soccer players, due to the large expected measurement error indicated by the wide limits of agreement. Shortcomings in the test administration may be responsible for these findings, thus, further research using more stringent guidelines for data collection is recommended.

5.4 Multi-stage Shuttle Test

The statistical analysis for the MST scores revealed a systematic bias towards players running further in test 2 than in test 1. Therefore, our results show that in this instance the MST was not found to be reproducible and is therefore deemed unsuitable for use in a youth soccer population, as administered in this study.

In the original study by Leger et al (1988), reliability was calculated as a retest correlation ($r = 0.89$ in children, $r = 0.95$ in adults), and therefore comparison of our findings to that of the original study is not possible. Although the correlation method is generally considered a good measure of reliability, it does not indicate bias, and as found with our data, any test re-test bias is important and must be investigated. In addition, correlation is also known to be largely dependant on the spread of values between participants (Hopkins 2000), therefore the correlation reported in the original MST study can only be regarded as valid for that particular group of subjects.

Test Bias

Given that the pre-test conditions were controlled, external factors such as fatigue and insufficient recovery should not have had an influence on the scores. It is possible that the systematic bias may be related to the subjects' motivation. In his review of measures of reliability, Hopkins (2000) highlights the likelihood that volunteers perform better in a 2nd trial due to the desire to improve. During a repeat measure of the MST the subjects are acutely aware of their previous performance in the test, as the audio cues allow a player to note the approximate level at which they are withdrawn from the test. It therefore seems natural that the players would try to beat their score on the next attempt regardless of any instruction given. It is also possible that the bias is indicative of a learning effect, which may be a result of the turning involved in the MST. Exposure to only the lower levels of the MST during the familiarisation sessions may not have prepare the subjects for efficient turning at the higher running speeds involved in the test. It is most probable that the bias is due to a combination of these factors which could have been avoided with the appropriate level of familiarisation. Therefore, it is recommended that further investigation be carried out to determine whether further familiarisation can reduce the extent of repeat measure variance.

5.5 Conclusions

The Squat Jump, Counter-Movement Jump and 505-agility test protocols were found to be reproducible with limits of agreement equal to ±0.06m (SJ), ±0.06m (CMJ), ±0.32s (505-L) and ±0.26s (505-R). The broad limits of agreement found for the Squat Jump and Counter-Movement Jump protocols suggest limitations in their use to detect fine changes in jump ability, and it may therefore be necessary to use more accurate laboratory methods when evaluating training interventions. Similarly, the 505-agility test protocol was found to exhibit a high degree of repeat measure error and therefore requires further investigation into the method of administration before being used as a means of performance assessment. Neither the 10m and 20m sprint tests or the multistage shuttle test protocols were found to be reproducible in this instance and therefore also require further investigation before being applied to the youth soccer population.

The findings of this study highlight the need for an awareness of measurement error in the application of performance assessments and the necessity of complete familiarisation. It is essential that sports science practitioners recognise the limitations of their chosen assessment methods, especially when using field-based tests that are poorly investigated among their chosen subject group.

5.6 Limitations and Recommendations

As the data collection was carried out during the playing season, access to subjects was largely restricted. Subject numbers were lower than anticipated due to a combination of injury, illness and last minute changes to match schedules. As a consequence of the low subject numbers for each age group, the individual squad data had to be combined for the statistical analysis. This introduced limitations to the applicability of our findings to the future analysis of individual squads.

The restricted access to subjects also affected the intended design of the study. A reluctance to interrupt the coaching programme meant that familiarisation had to be kept to a minimum and the time between tests had to be 14 days rather than the 7 days adopted by other reliability studies. It is recommended that clubs looking to implement sport science interventions to the coaching programme recognise the importance of this type of investigation and address the needs of the sports scientist with the same degree of importance as all other aspects of coaching.

Finally, the application of the test battery in one single session was necessary due to time constraints, but in the practical application of such tests throughout the playing season it may be more appropriate to separate the test protocols into 2 or more sessions. This would remove the potential for boredom and mental fatigue affecting the players' motivation.

Appendix 1

Parents' Information Sheet
The reproducibility of a fitness test battery in youth soccer players.

Introduction

Scientists from the University of Glasgow are currently investigating methods of fitness assesment in youth-soccer players aged between 11 & 18 years. The practice of regular fitness assesment in adult soccer players is becoming more popular with professional football clubs, and has proven to be a succesful contributor in raising the standard of fitness at many football clubs worldwide. With the growing demand for succesful youth development programs in Scottish football it is not surprising that these practices are being introduced to the younger squads in the hope of improving the standards at an earlier age. However, most of the fitness tests in use in football today have only been investigated in an adult population and may not give accurate results when applied to younger players. So before a test can be considered to be appropriate, there is a need to determine how reproducible the test scores are so that it is possible to asses if meaningful changes in the training status of the players have taken place.

The aim of this study is to investigate the reproducibility of a selection of fitness tests in youth soccer players and to quantify the extent of variability, in order to allow the accuracy of the tests to be determined. It is hoped that this information can help to establish valid methods of fitness assesment for the youth population .

Why has your child been asked to take part in the study?

The Football club have expressed an interest in introducing fitness assesments to the current training program, and have agreed to allow willing participants from the youth squads to participate in the study. The club hopes to be able to integrate valid fitness tests into the regular training program in the future.

Does your child need to take part?

There is no pressure on anyone to take part. **It is emphasised that participation in the study is on a voluntary basis and will have no bearing on your relationship with the football club.** If you do agree to become involved you or your child can choose to withdraw from the study at any point should you not want to continue.

What does the study involve?

The players will perform a selection of fitness tests on 2 separate occassions with 14 days between the tests. We will compare the results to look for any differences. If the testing methods are accurate, then there should be no major differences in the results over such a short period of time. We will also be required to take measurements of height, weight and body fat percentage. The exact procedures involved are explained in greater detail in the next section.

What will you and your child have to do?

You are asked to complete the enclosed medical questionairre and consent form to determine your child's suitability for participation. This information will be kept strictly confidential and only used to determine how safe it is for your child to take part.

Participants will the be asked to take part in the following, which will take place at the stadium, and will be arranged by the club coaching staff:

Familiarisation. (Approximately 90 minutes, group session)
Players will be instructed on each of the testing methods and then carry out each of the tests in a group setting. This initial session is used to familiarise players with the testing methods.

Body Composition assessment. (Approximately 15 minutes per player)
Measurements of height and weight will be taken; players are required to wear shorts and remove footwear and upper body clothing for this. An adult chaperon is required to accompany each player during this session. Parents are welcome to chaperon their own child. A measure of blood pressure (measured using an electronic arm cuff) will also be taken.

Test Session 1. (Approximately 90 minutes, group session).

The group performs each of the fitness tests in turn (see test protocol sheet at the back of this document).

Test Session 2. (Approximately 90 minutes, group session).

The tests are repeated exactly as in test session 1.

The tests will be carried out by Pamila Doyle (Post-graduate research student), who will be assisted by staff and students from the university. Coaching staff from the football club will also be present at the sessions. All personell involved will have undergone a criminal disclosure check and posses the neccesary documentation to work with children.

What are the possible benefits of taking part?

Players will be given a report detailing their performance on each of the tests. This will provide baseline measurements that can be used by coaching staff to set training programmes, and monitor the future progress of the team. Body composition information is also useful in monitoring the physical development of the younger players.

Are there any risks involved? What if something goes wrong?

The risks involved are deemed to be no more than those involved in everyday participation in football training. However, research has shown that there is a small cardiac risk associated with participation in maximal exercise. To minimise this risk, players whose medical circumstances put them into the higher risk category will not be allowed to participate. Should any medical emergency arise, there will be at least two people present who are trained in life support techniques and equipped with a first aid kit, emergency oxygen cylinder and semi-automated defibrillator.

Will participation in this study be kept confidential?

All information collected in this study will be treated in a confidential manner and each player's involvement will be kept anonymous. It is the intention of the university to publish the findings of this research in the near future.

It is also the intention of the football club to use these results to establish future training programs; however this information will only be released to the club with the permission of the player, parent or guardian. It is stressed that performance in the tests will have no bearing on team selection in the future and will only be used for training purposes.

If you are worried about your involvement in this study or have any further questions about what is involved, please contact:

Dr Stan Grant
West Medical Building
University of Glasgow
Glasgow
G12 8QQ
Phone: 0141 3306490
Fax: 0141 330 2923
E-mail: s.grant@bio.gla.ac.uk

Test Protocols

Body Composition

Measurements of blood pressure (measured using an electronic arm cuff), height, and weight will be taken.. Players are required to wear shorts and remove footwear and upper body clothing. An adult chaperon is required to accompany all players under the age of 16 during this session. Parents are welcome to chaperon their own child.

Jump Tests

Players perform 2 types of vertical jump whilst standing on a measurement mat. The first jump is performed with the hands remaining on the hips at all times and the second with a counter movement of the arms to assist. Each player performs 3 attempts of each jump, with the aim of jumping as high as possible. A minimum of 1-minute recovery period seperates each jump.

Sprint Tests

Players sprint times are measured using electronic sprint gates. The fastest 10M and 20M sprint times are recorded from 3 maximal attempts. A minimum of two-minutes recovery seperates each attempt. Players jog gently and keep active between sprints.

Agility Tests

The players perform a soccer-specific agility test that involves sprinting over a 20m distance with a directional change after 15m. The fastest time is recorded from 3 atempts with a left turn, and 3 attempts with a right turn. Again each attempt is seperated by a minimum two-minute recovery period.

Multistage Shuttle Test

The multistage shuttle test is used to measure endurance performance. Players run back and forth over a 20m distance in time to pre-set bleeps on an audiocassette. Every minute, running speed increases slightly. The test lasts approximately 5 – 15 minutes depending on fitness levels. Players run to volitional exhaustion, with the instruction to run as long as possible.

Appendix 2

University of Glasgow
Institute of Biomedical & Life Sciences
Subject Questionnaire and Consent Form for High Intensity Exercise Testing
(Under 16 years – to be completed by a Parent or Guardian)

Fitness Tests: Anthropometric assessment, Maximum Jump Height (Power), 10M & 20M Sprint Time (Speed), 505 Agility Run (Agility), Multistage Shuttle Test (Aerobic Power).

Childs Name: ....

Sex: M/F **Age:** .... (Yr)

Illnesses: Does your child suffer from any of the following? *(Please circle NO or YES)*

Anaemia	NO / YES	Asthma	NO / YES
Diabetes	NO / YES	Epilepsy	NO / YES
Heart Disease	NO / YES	High Blood Pressure	NO / YES
Fainting Bouts	NO / YES	Other*	NO / YES

* *(Please Specify)*
....

Medication: Is your child currently taking any medication? NO / YES

* *(Please Specify)*
....

Family History of Sudden Death:

Is there a history of sudden death in people under 40 years in your family? NO / YES

Muscle or Joint Injury:

Has your child been advised by the club coach/physiotherapist not to take part in training due to any muscle or joint injury? NO / YES

Can you think of any reason why your child should not take part in high intensity fitness testing? NO / YES*

* *(Please Specify)*
....

Blood Pressure (resting)

.... (mmHg)

Screened by: .... Date: ....
:

Consent Statement:

I .... (Parents Name) agree to my child

.... (Childs Name) taking part in the fitness tests and research study named above, the details of which have been explained clearly to me.
I understand that should I choose to, I or my child can withdraw from the study at any time.

Signed: .... **Date:** ....

Students Signature: .... **Date:** ....

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