PHYSICAL DEVELOPMENT, AND PROGRESSION TO PROFESSIONAL SOCCER, OF ELITE CHILD AND ADOLESCENT ACADEMY PLAYERS.

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ABSTRACT

The research described within this thesis was undertaken to investigate the physical development, and progression to professional soccer, of elite child and adolescent academy players. Firstly, a detailed understanding of professional practitioners perceptions of physical performance in soccer was developed. Secondly, a valid and reliable battery of physical field tests was established to examine the physical performance characteristics of elite child and adolescent soccer players. Finally, this battery of physical performance tests was administered to elite child and adolescent players in English professional soccer academies over a three year period.

Coaches (n=170), fitness professionals (n=172) and players (n=101) perceptions of physical performance in soccer were assessed by means of a questionnaire. Speed was considered the principle physical attribute by coaches, with 80.5% deeming it as 'very important'. Most coaches (88.8%), fitness professionals (93.0%) and players (89.1%) believed the relative importance of each physical attribute differed according to playing position. A players physical attributes were regarded by coaches as 'important' (44.1%) and 'very important' (41.8%) in the process of offering professional playing contracts. Most coaches (71.2%), fitness professionals (68.6%) and players (65.3%) thought international players physical attributes were different to club players. Nearly all coaches (93.5%), fitness professionals (86.6%) and players (83.2%) believed the physical attributes of players had become more important in the modern day game. It was widely considered by coaches (73.5%), fitness professionals (52.9%) and players (74.3%) that players from certain ethnic groups were naturally more physically able.

Logical validity of physical performance testing was demonstrated by the majority of coaches (97.0%), fitness professionals (93.5%) and players (83.1%) considering testing to be an important aspect of preparation in soccer. Construct validity of vertical jump (RJ; CMJ; CMJA), sprint (10 m and 20 m) and agility tests was shown by their ability to distinguish between different age groups ($p<0.01$) and ability groups ($p<0.05$) of players. Absolute reliability of the physical performance tests was established with repeatability on the vertical jump tests ranging from 3.2 cm to 3.5 cm for the RJ and CMJA, respectively, whilst repeatability on the sprint tests ranged from 0.07 s to 0.24 s on the 10 m sprint and agility test, respectively. ICC and PCC values to assess the relative reliability of the physical performance tests were all 'high' (>0.90) ranging from 0.96 for the agility test to 0.99 for the 20 m sprint.

Anthropometric measurements and physical performance tests (RJ; CMJ; CMJA; sprint 10 m and 20 m; agility) were administered to 2,252 elite child and adolescent soccer players from U9 to U19 age groups (age 13.6±2.8 years; standing height 159.9±16.5 cm; body mass 51.6±16.2 kg). Estimated peak oxygen uptake ($\dot{V}O_{2peak}$) was measured in 727 players using the MSFT. Peak height velocity (PHV) and peak body mass velocity (PWV) of the elite players occurred at 14.2 years of age, ~9.0 $cm.yr^{-1}$ and 8.6 $kg.yr^{-1}$, respectively.

Significant positional differences in the U9 to U19 age groups were found in standing height and body mass, goalkeepers and centerbacks were taller ($p<0.05$) in relation to other positions, in particular fullbacks ($p<0.05$) and midfielders ($p<0.05$). Goalkeepers and centrebacks were heavier ($p<0.05$) in relation to other positions, especially when compared to midfielders ($p<0.05$). Forwards jumped significantly higher ($p<0.05$) in the U13 and U16 age groups in comparison to fullbacks ($p<0.05$) and midfielders ($p<0.05$). Goalkeepers were slower (10 m and 20 m sprint and agility) in comparison to outfield players ($p<0.05$). No significant differences were observed between outfield players in terms of estimated $\dot{V}O_{2peak.}$ Goalkeepers estimated $\dot{V}O_{2peak}$ was significantly lower in comparison to some outfield positions in the U12, U13 and U15 age groups ($p<0.05$).

The ethnic group of the majority (85.4%) of the 2,252 academy players studied was White. Black Caribbean (7.8%) and Black African (5.2%) were the second and third largest ethnic groups, respectively. Black Caribbean and Black African players were significantly taller than White players in the U12 and U13 age groups, respectively (156.2 ± 8.2 cm vs. 151.1 ± 7.4 cm and 165.9 ± 9.4 cm vs. 157.2 ± 8.6 cm, respectively, $p<0.05$). Black African and Black Caribbean players were significantly heavier than White players in the U9 and U18 age groups, respectively (34.6 ± 3.3 kg vs. 30.6 ± 3.5 kg and 77.3 ± 8.8 kg vs. 72.4 ± 6.5 kg, respectively, $p<0.05$). Vertical jump performance (RJ; CMJ; CMJA) of the Black African and Black Caribbean players was significantly better than the White players in the majority of the age groups studied (for example, U16 RJ, 42.5 ± 4.1 cm and 40.8 ± 6.6 cm vs. 36.9 ± 4.5 cm, $p<0.05$). Significant differences in sprint performance between the Black African and Black Caribbean players in comparison to the White players were found in four age groups (U10; U12; U14; U18; $p<0.05$) in the 10 m sprint and six age groups (U10; U12; U14; U16; U17; U18; $p<0.05$) in the 20 m sprint. No significant differences in estimated $\dot{V}O_{2peak}$ were found to exist between the different ethnic groups studied. Most White players were midfielders (35.3%), with 8.9% being goalkeepers. Most Black Caribbean (40.9%) and Black African (35.0%) players were forwards, with only 0.9% and 3.4%, being goalkeepers, respectively. The playing position distribution of the Black Caribbean and Black African players was significantly different to expected playing position distribution for academy players ($p<0.001$).

A relative age effect was evident in the 2,252 academy players, with 46.5% and 9% of players having birthdates between September - November (1st Quarter) and June – August (4th Quarter), ($p<0.01$). This relative age effect was evident in all academy age groups from U9 to U19. Those players born in the early part of the selection year were taller (U10, U11, U13, U14, U15; $p<0.05$) and heavier (U10, U12, U13, U14, U18; $p<0.05$). Players born in the early part of the selection year could jump higher, (RJ – U10, U17, U19; $p<0.05$; CMJA – U9, U10, U19; $p<0.05$), sprint faster (20 m - U14, U15; $p<0.05$) and were more agile (U12; $p<0.05$).

Stage of sexual maturation was assessed in 382 elite child and adolescent soccer players (age 13.6 ± 2.8 years; height 159.2 ± 16.2 cm; body mass 51.4 ± 15.9 kg). Significant differences in the standing height ($p<0.05$) and body mass ($p<0.05$) of players grouped by stage of sexual maturation were found in the U12 to U15 and U12 to U16 age groups, respectively. Significant differences in vertical jump height grouped by stage of sexual maturation were found in the U12, U13, U15 and U16 age groups ($p<0.05$). Similar significant differences were found in 10 m sprint (U13; $p<0.05$) and 20 m sprint (U11; U12; U13; $p<0.05$).

Longitudinal data was collected on 2,252 subjects who completed between 1 and 6 testing sessions over 3 seasons (6088 data points). Multilevel additive polynomial analysis of standing height and body mass suggests a peak increase in standing height (6.5 $cm.yr^{-1}$) and body mass (5.8 $kg.yr^{-1}$) velocity at 12.3 and 13.8 years, respectively. Multilevel multiplicative allometric analysis suggested that the peak rate of change in 10 m (0.13 $m.s.yr^{-1}$) and 20 m (0.17 $m.s.yr^{-1}$) speed occurred at 12.3 years, the peak rate of change in RJ (1.86 $cm.yr^{-1}$), CMJ (2.00 $cm.yr^{-1}$) and CMJA (2.41 $cm.yr^{-1}$) height at 13.3 years, and the peak rate of change in agility (0.15 $cm.yr^{-1}$) at 7.3 years.

Elite academy players (international academy players, n=98; club academy players, n=1687) and non-elite school pupils (school players, n=209; non-players, n=311) from U11 to U18 were compared. A significant difference in vertical jump (RJ; CMJ; CMJA), sprint (10 m and 20 m), agility and estimated $\dot{V}O_{2peak}$ between academy players and school pupils was found ($p<0.01$). Whilst academy players were 6.4 times more likely to be faster over a 10 m sprint, agility was found to be the most distinguishing characteristic with academy players being 60.3 times more likely to be faster on the agility test than school pupils ($p<0.05$).

Retained (n=1808) academy players were significantly taller and heavier ($p<0.01$) than released academy players (n=444). Vertical jump (RJ; CMJ; CMJA), sprint (10 m and 20 m), agility and estimated $\dot{V}O_{2peak}$ was significantly better in the retained players as opposed to the released players ($p<0.01$). The variable best able to distinguish between retained and released academy players was agility, with retained players 1.95 times more likely to be faster over the agility test than released players ($p<0.05$).

A total of 771 elite child and adolescent soccer players were assessed by coaches as being ‘above average’ (n=198), ‘average’ (n=485) or ‘below average’ (n=88) for their respective academy age group in terms of ‘global soccer ability’. ‘Above average’ players were found to jump higher (RJ; CMJ; CMJA), sprint faster (10 m and 20 m), be more agile and possess a higher estimated $\dot{V}O_{2peak}$ compared to ‘average’ and ‘below average’ players ($p<0.01$). Agility was the key distinguishing factor between ‘average’ and ‘below average’ players, with ‘average’ players 2.28 times more likely to be faster on the agility test ($p<0.05$).

The professional status of 954 academy graduates (age 16.3±1.6 years; height 174.3±8.7 cm; body mass 66.1±10.8 kg) was established. Professional playing contracts were awarded to 197 (20.6%), with 123 (12.9%) of these players having made a professional playing appearance. Professional academy graduates were significantly taller and heavier than non-professional academy graduates (177.1±7.3 vs. 173.5±8.8 cm and 69.2±9.3 vs. 65.3±11.0 kg, respectively; $p<0.01$). Professional academy graduates had significantly higher vertical jump scores than non-professional academy graduates (RJ 38.8±5.4 vs. 36.6±5.4 cm, CMJ 39.4±5.6 vs. 37.5±5.5 cm and CMJA 45.6±6.5 vs. 42.8±6.4 cm, respectively; $p<0.01$). Professional academy graduates had significantly faster sprint and agility times than non-professional academy graduates (10 m sprint 1.72±0.1 vs. 1.75±0.1 s, 20 m sprint 2.99±0.1 vs. 3.07±0.2 s and agility test 4.09±0.3 vs. 4.26±0.3 s, respectively; $p<0.01$). No significant differences in estimated $\dot{V}O_{2peak}$ values were found between players who were and were not awarded professional playing contracts (57.6±4.4 vs. 57.1±4.1 $ml.kg^{-1}.min^{-1}$, respectively). Multilevel analysis suggested the key discriminating characteristics of professional academy graduates were that they were taller than their peers and had better agility ($p<0.05$).

The results outlined within the thesis provide a better understanding of physical performance in relation to the elite young and adolescent soccer player. The research findings presented are based on the largest and most comprehensive investigation of its kind to date, both in terms of the number of elite young players (2,252) and the range of age groups (U9s to U19s) studied. These findings have highlighted the importance attached to a young players physical development in the process of progressing through elite academies into professional soccer. The key finding of the thesis is that agility is the most important physical characteristic distinguishing between different groups of players including those who do and those who do not go on to sign a professional contract.

The studies described herein have been reported elsewhere and the following is a list of relevant publications and conference presentations:-

Hulse, M.A. (2003). Physical and physiological characteristics of elite youth football players. *Insight*. 3 (6) 20-22.

Hulse, M., Hawkins, R., Morris, J., Hodson, A. and Nevill, M. (2005). A cross-sectional analysis of the anthropometric and physiological development of young, elite soccer players. *Journal of Sports Sciences*, 23 (11/12):1290-1291.

Hulse, M., Morris, J., Hodson, A. and Nevill, M. (2007). Validity and reliability of physical field based performance tests in elite child and adolescent soccer players. *Journal of Sports Sciences*, 25 (3):235-369.

Hulse, M., Morris, J., Nevill, A., Hodson, A. and Nevill, M. (2008). Relative age and performance in English Academy footballers. In: *Researching Youth Football: Multidisciplinary Dialogues*.

Hulse, M., Morris, J., Nevill, A., Savard, C. and Nevill, M. (2008). Physiological contributors to retention within academies and progression to professional football of English youth players. In: *Researching Youth Football: Multidisciplinary Dialogues*.

Hulse, M., Morris, J.G. and Nevill, M.E. (2010). Anthropometric and physical performance characterisitics of young elite football players, categorized by ability. World Conference on Science and Soccer.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1
INTRODUCTION

1.1 INTRODUCTION

Research has provided us with a detailed understanding of the physical demands that soccer places on adult players, both in terms of the distance covered and the nature and patterns of activity during a game (Bangsbo, 1994a; Reilly, 1997; Ekblom, 1986). Based on the physical demands that have been identified, researchers have investigated various physical, physiological and anthropometric characteristics of elite players (Reilly et al., 2000; Reilly, 1994a; Rienzi et al., 2000). Many of the decisive moments in a game are played out when a player is sprinting, jumping, accelerating or changing direction at speed. It has been suggested that the ability to accelerate quickly over short distances and agility are the two main factors that are characteristic of soccer players, distinguishing them from players in other codes of football (Reilly et al., 2000). In the context of elite soccer the assessment of physical performance can often be based on the opinions and beliefs of coaches, players and support staff. Despite the importance placed on such subjective observations no research has been conducted that reflects on the outlook of those involved in the game in relation to physical performance in soccer.

Many of the initial studies relating to the physical performance characteristics of soccer players employed laboratory based tests (Faina et al., 1988; Tumilty, 1993). Today, practitioners working with squads more often adopt soccer specific field-based tests as opposed to traditional laboratory based assessments, allowing greater numbers of players to be assessed and for the testing to more closely reflect movement patterns in soccer (Reilly and Gilbourne, 2003). A wide range of fitness attributes have been examined in soccer players, including, endurance, power, strength, speed, flexibility and agility (Oberg et al., 1986; Kirkendall, 1985; Raven et al., 1976; Thomas and Reilly, 1979; Davis et al., 1992; Kollath and Quade, 1993; Brewer and Davis, 1992). Although the nature and type of physical testing varies from study to study, a number of more commonly used field tests are evident in the literature, including, the continuous multistage fitness test (Brewer et al., 1988); vertical jump height (Bosco et al., 1983); and acceleration and speed tests (Tumulty, 2000). Much debate exists however, with regard to the best method of testing agility, with several tests being reported by various authors, including the Illinois agility test (Hastad and Lacy, 1994), 505 agility test (Draper and Lancaster, 1985) and a football specific sprint test (Bangsbo, 1994c). However, an accepted battery of valid and reliable field test protocols has yet to be developed for soccer players. The development of such a test battery would allow for comparisons of different levels of player performance, in relation to age, maturity, playing position, ethnicity, and playing standard.

In England the advent of soccer academies in 1998 resulted in players being recruited to professional clubs at increasingly younger ages, with the recruitment of players under nine years of age the norm. At these young ages elite selected players will begin systematic training and specialization in soccer. Thus the process of identification and selection of talented individuals has become increasingly important. The limited amount of research previously conducted with youth players has generally focused on players during the later stages of their development (le Gall et al., 2010; Jungi et al., 1997; Leatt, Shephard and Plyley, 1987; Jankovic et al., 1993). No study to date has reported on the physical performance of elite players throughout the full spectrum of youth football, with squads ranging from under nine to under nineteen years of age.

The physiological demands of soccer have been shown to vary with the work-rates associated with different positional roles (Reilly, Bangsbo and Franks, 2000). For this reason a number of studies reporting on physical performance in soccer have investigated players in relation to their respective positional groups, with differences in the physiological profiles of players being found to exist between different playing positions (Reilly, 1994; Rienzi et al., 2000). The majority of the studies which have described the anthropometric and physical performance characteristics of different playing positions have been based on the analysis of elite senior players (Reilly, 1994; Bangsbo and

Michalsik, 2002; Rienzi et al., 2000). The lack of similar studies available on young soccer players has been previously noted by Gil and colleagues (2007). It is also apparent that studies involving younger players are limited to a small selection of age groups (Franks et al., 1999; Malina et al., 2000; Neto et al., 2003). No comparison of the anthropometric and physical performance characteristics of elite young soccer players in relation to specific playing positions throughout a broad range of age groups has been conducted to date.

It has been contended that Black players may be assigned to playing positions on the foundation of racial stereotypes of abilities (Maguire, 1988). Earlier observations on the overrepresentation of Black players in English soccer have also been made (Maguire, 1988). In general the study of race-based differences and physical performance has been limited to critical sociological work. Much of this work has simply commented on anecdotal evidence of better physical performances by Black athletes in certain sports, for example, basketball and American football. An investigation of Polish Basketball players by Zajac and colleagues (2000) is one of the few studies to actually compare the anthropometric and physical performance characteristics of elite Black and White athletes. Thus far there are no studies that have commented on the physical performance of elite soccer players at either the senior or junior level in relation to ethnic background.

In youth soccer players are divided into chronological age categories based on their date of birth. In English academies the selection year starts on the 1st September and finishes on the 31st August and players are selected from individuals born in the same 12 month period. Consequently, within the same age group a difference of nearly one year can exist between the oldest and youngest players. As a result of this a relative age effect has been documented in elite youth soccer whereby there is a bias towards the recruitment of individuals born early in the selection year (Brewer et al., 1995; Musch and Hay, 1999; Simmons and Paull, 2001; Jimenez and Pain, 2008; Carling et al., 2009; Williams, 2009). The main explanation put forward to account for the relative age effect in elite youth soccer has focused on the suggestion that players born earlier in the selection year are more advanced in terms of physical development and performance (Malina et al., 2007). However, whilst these suggestions have been made, only Carling and colleagues (2009) have investigated the association between physical characteristics and the relative age effect in French players aged from 14 to 16 years. No studies to date have examined the relationship between physical performance and the relative age effect in a wide range of age groups.

The implications of the processes of growth and maturation mean that the young soccer player is subjected to considerable change, both in terms of their anthropometric and physical performance characteristics. Katzmarzyk and colleagues, (1997) reported that at a given skeletal maturity, variation in chronological age may be considerable, highlighting that chronological age and skeletal maturity rarely progress at the same rates. Therefore, within a given chronological age group some players may be advantaged or disadvantaged in the performance of physical fitness tests due to their maturity status, especially when comparing results to age specific normative values (Beunen et al., 1997). Thus, players who mature earlier are likely to have distinct physical advantages compared with players who mature at a later chronological age. Given the physical nature of soccer this could mean the difference between success and failure, or selection and non-selection. In other sports such as swimming and tennis, it has been shown that early maturers, as identified by testicular volume, do tend to be preferentially selected for national age group squads (Baxter-Jones et al., 1995). However, there is no such information for soccer players.

The few studies which have focused on talent identification in soccer or the factors which distinguish an elite from a non-elite group have been restricted to specific age groups of players and consequently the number of players involved has been limited. For example, in a study of 16 elite and 15 sub-elite players aged 15 to 16 years Reilly and colleagues (2000) suggested that agility was the most powerful discriminator between the two groups of players. More research is required over a wider range of ages with a larger number of players to identify the physical differences that may exist for example between retained and released academy players. Furthermore, there is very little research examining those physical or physiological characteristics that may distinguish players who go on to become professional soccer players from those that do not, with just one study showing no difference in anthropometric variables (Franks et al., 2002).

Thus the overall purpose of this thesis was to document and examine the physical development, and progression to professional soccer, of elite child and adolescent academy players associated with professional clubs in England. As a result the following studies are described within this thesis:

1. the analysis of coaches, fitness professionals and players understandings of the physical aspects of performance in soccer,
2. the development of a valid and reliable physical performance testing protocol to assess the physical/physiological attributes of elite child and adolescent players,
3. the development of normative values of physical performance for elite child and adolescent players from under 9 to under 19 age groups,
4. the analysis of elite child and adolescent players physical performance in relation to playing position and ethnic group,
5. the analysis of a relative age effect in elite child and adolescent players and the effect of maturation on physical performance,
6. multilevel modelling of the longitudinal development of elite child and adolescent players anthropometric and physical performance characteristics,
7. the analysis of the physical/physiological characteristics of child and adolescent players in relation to their playing standard and the implications for the process of talent identification.

The hypotheses to be tested were that:

- coaches, fitness professionals and players perceive the physical aspects of performance in soccer to be very important in the context of the elite player,

- physical based field tests provide a valid and reliable tool for the assessment of physical/physiological performance characteristics in elite young players,
- the physical performance of elite young players in professional English soccer academies improves with chronological age from the under 9 to under 19 years age group squads,
- the anthropometric and physical performance characteristics of elite young players varies in relation to playing position,
- elite young Black players will perform better than elite young White players on soccer specific physical performance tests,
- the selection process in elite youth soccer currently favours the older and more mature players,
- players advanced in biological maturity demonstrate a better level of physical performance,
- the greatest changes in physical performance occurs at the time corresponding with the peak height or weight velocity,
- soccer ability group (non-players vs. school players; school pupils vs. academy players; club academy players vs. international academy players) could be distinguished on the basis of anthropometric and/or physical performance characteristics,
- retained academy players would have better physical performance characteristics than released academy players and that agility might distinguish best between retained and released players,
- anthropometric and/or physical performance characteristics could distinguish between elite young players placed in different ability groups on the basis of coach opinion,
- academy players who went on to sign a professional contract would be best distinguished by agility.

1.2 ORGANISATION OF THESIS

This thesis is presented in nine main chapters. The review of literature (Chapter 2) examines all the available studies documenting the physical and physiological performance characteristics of elite soccer players. The physical demands of soccer match-play are discussed along with methods of assessment that have been used to assess the physical performance characteristics of players. Special reference throughout the review of literature is given to the elite young player and the process of growth and maturation.

The general methods (Chapter 3) detail all the physical performance testing procedures and guidelines which form the basis of the analysis throughout the thesis. An outline of the design, administration and analysis of the questionnaire that was used to investigate physical performance in soccer is also provided.

Physical performance in soccer (Chapter 4) is examined in relation to the current beliefs and opinions of coaches, fitness professionals and players expressed in their respective questionnaire responses. The relative importance of the various aspects of physical performance and physical performance testing are discussed.

The validity and reliability of physical performance testing (Chapter 5) is discussed in relation to the elite soccer club environment. The study considers the appropriateness of physical field-based performance tests as a tool to assess young elite soccer players.

The young elite soccer player (Chapter 6) comprises a detailed description of the anthropometric and physical performance attributes of Under 9 to Under 19 year old elite players. The influence of playing position and ethnic group are also discussed in relation to the anthropometric and physical performance characteristics of elite young players.

Relative age and maturation (Chapter 7) are examined within the context of professional English soccer academies. Evidence of a relative age effect is discussed in relation to the season of birth distribution of elite young players with special reference to the observed trends in physical performance. The physical performance characteristics of elite young players is also analysed within the framework of the maturation process.

Longitudinal development (Chapter 8) of anthropometric and physical performance characteristics of elite academy players was analysed using multilevel modelling.

Physical performance and playing ability (Chapter 9) investigates the associated differences in players anthropometric and physical performance characteristics across a wide range of playing levels. Comparisons of anthropometric and physical performance characteristics are made between non-elite and elite young players, released and retained academy players, coach assessed academy playing ability groups and non-professional and professional academy graduates.

The general discussion (Chapter 10) provides an overview of the major findings from the studies which form the composition this thesis on the physical performance characteristics of elite child and adolescent soccer players.

CHAPTER 2
REVIEW OF LITERATURE

2.1 INTRODUCTION

This review of literature examines the physiological demands of soccer and the anthropometric and physiological characteristics of elite soccer players. Special consideration is given to the laboratory and field-based fitness tests that have been used to examine soccer players' physical capabilities. Specific reference throughout the review is given to the young player and the effects of growth and maturation on physical performance throughout the childhood years.

2.2 MATCH ANALYSIS IN SOCCER

The game of soccer is played for 90 min, consisting of two 45-minute halves with a 15-minute break at half-time. Some games may necessitate 30 min of 'extra time' in order to produce a definite result. The actual playing time, which is referred to as the time with the ball in play, varies considerably (Tumilty, 1993; Withers et al., 1982). Time-motion analysis studies have shown soccer to be a high intensity intermittent exercise activity (Ekblom, 1986). Kirkendall (1985) described soccer to be a 'hybrid' game in which players are required to repeatedly run short distances at a variety of speeds, whilst also covering a substantial distance over the course of a game.

2.2.1 Distance covered

A large number of researchers have attempted to measure the distance covered by individual players during a game (Table 2.1). It is apparent that differences in tactics employed, styles and systems of play, the nature of the game and opposition, and the physical capacity of the player's can all influence distances covered. A recent study by Mohr, Krustrup and Bangsbo (2003) found that within each playing position there was a significant variation in the physical demands depending on the tactical role and the physical capacity of the players.

The distance covered during a game has also been related to the level of competitive play, the higher distances being covered in the top leagues (Reilly et al., 2008). It has also been suggested that, because of greater levels of competition, there has been a move towards a faster pace of play and therefore an increase in the distance covered over the course of a game (Shephard, 1998). Strudwick and Reilly (2001) provide evidence that the distance covered by players in the top English league was increased after the Premier League was inaugurated in 1992.

Table 2.1. Summary of reported distances covered by players during a game.

Study	Players	Distance Covered (km)
Saltin (1973)	Non-elite (Sweden)	11.5
Whitehead (1975)	Professional (England)	11.7
Reilly and Thomas (1976)	Professional (England)	8.7
Withers et al. (1982)	1st Team (Australia)	10.5
Ekblom (1986)	1st-4th Division (Sweden)	10.0
Gerisch et al. (1988)	Top amateurs (Germany)	9.0
Ohashi et al. (1988)	International (Japan)	9.8
Bangsbo et al. (1991)	1st – 2nd Division (Denmark)	10.8
Miyagi et al. (1998)	University (Japan)	10.8
Rienzi et al. (2000)	Internationals (South America)	9.8
Strudwick and Reilly (2001)	Premier league (England)	11.3
Mohr, Krustrup and Bangsbo (2003)	1st Division (Denmark) 1st Division/Champions league (Italy)	10.3 10.9

The distance covered by players in different positions has been found to vary significantly (Reilly and Thomas, 1976; Ekblom, 1986; Bangsbo et al., 1991; Strudwick and Reilly, 2001) with midfield players covering a greater distance during a match than other players (Figure 2.1). The greater distance covered by midfield players is suggested to be a product of both higher levels of fitness associated with such players and the role which they play in the team, linking between defense and attack, a role which evidently requires more sustained running (Bangsbo, 1994a).

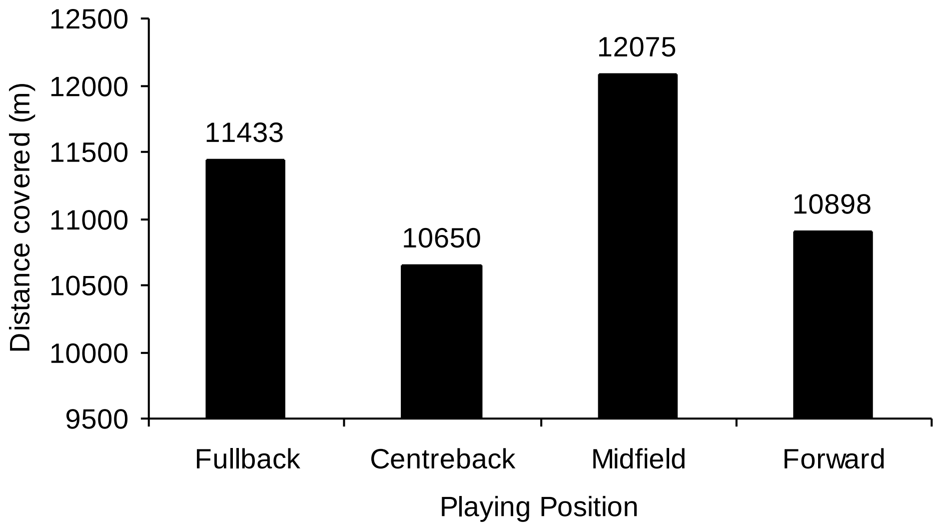


Figure 2.1. Mean distances covered during a game according to playing position (From Strudwick and Reilly, 2001).

2.2.2 Nature and patterns of activity in soccer

The pattern of exercise in soccer is intermittent and throughout the course of a game players are constantly switching between many different activities. In the past it has been observed that players perform approximately 1,000 discrete activities during a game, each lasting 5-6 seconds on average (Reilly and Thomas, 1976). More recently the total number of activities performed during a game was found to be 1,525, amounting to a change in activity every 3.5 seconds (Strudwick and Reilly, 2001). A number of studies have broken down the distances covered during games into specific modes of movement, providing a further insight into the physiological requirements of soccer (Table 2.2).

Table 2.2. Distances covered in different modes of movement as a percentage of the total distances.

Study	Players	Position	Walk	Side/back	Jog	Cruise	Sprint
Reilly and Thomas (1976)	Professional (England)	Full-back	27.8	8.1	35.2	19.2	9.5
		Centreback	22.9	8.4	37.5	20.6	10.7
		Midfield	20.7	5.2	41.2	22.0	10.8
		Forward	27.5	5.9	33.0	20.9	12.7
Withers et al. (1982)	Semi-pro (Australia)	Full-back	23.7	8.9	45.0	14.5	7.9
		Centreback	30.3	15.3	37.9	12.5	3.9
		Midfield	21.9	7.8	49.9	15.1	5.3
		Forward	29.8	10.1	44.4	10.0	5.8
Van Gool et al. (1988)	University (Belgium)	Defence	44.9	/	49.1	10.0	/
		Midfield	39.0	/	53.2	6.0	/
		Forward	47.1	/	44.1	7.7	/
Ohashi et al. (1988)	International (Japan)		31.1	/	56.1	10.5	2.3
Reilly (2000)			25	7	37	20	11
Rienzi et al. (2000)	International (South American)	Defenders	31	14	45	8	3
		Midfielders	25	12	49	11	3
		Forwards	39	9	34	12	7
Strudwick and Reilly (2001)	Premier League (England)		36	5	38	10	3

Despite the differing methods used, what is clear is from these studies is that the greatest proportion of a player's movement is at low speeds. The ratio of work for English Premier League players in terms of high, low and rest was found to be 1:16:3 (Strudwick and Reilly, 2001).

Characteristic patterns of movement modes have emerged in relation to playing position. Midfielders are observed to cover a greater percentage of their total distance at a jog, attackers it is suggested cover more of their distance at a sprint, whilst centre-backs cover more distance moving sideways or backwards (Reilly and Thomas, 1976; Withers et al., 1982; Van Gool et al., 1988; Bangsbo et al., 1991; Rienzi et al., 2000) (Table 2.3).

It is worth noting that the distance covered in possession of the ball is very small (~158 m), 1.7% of the total distance (Reilly and Thomas, 1976). Similarly Rico and Bangsbo (1993) found the average time in possession for Danish international players amounted to 1.3 min. Therefore, the majority of movement in a game is ‘off’ the ball, attempting to gain or receive possession.

In summary, the demands of soccer are best described as high intensity, non-continuous intermittent exercise (Ekblom, 1986).

2.2.3 Match analysis in youth soccer

Given the overwhelming popularity of soccer compared with other youth sports, the scarcity of information on the technical, physiological and conditioning aspects of pre-pubescent and other youth players is surprising (Capranica et al., 2001; Billows et al., 2003; Stroyer et al., 2004). Until recently young players have often been required to compete on regular sized pitches, regardless of age or size differences. In some countries, in particular England and the United States of America (USA), the rules of youth soccer now differ from those of the senior game. For example, in the USA players under the age of 8 years have a game that is divided into four 12 minute quarters, whilst players under 10 years play two 25 min periods. The pitch dimensions are also reduced, and seven players per side play in under 8 and under 10 games (Bar-Or and Unnithan, 1994). Unlimited substitutions are permitted at all junior levels in the USA, with the exception of national under 16 games, in which only two substitutions are allowed (Shephard, 1999).

In England the advent of Professional Soccer Academies in 1998 led to dramatic changes concerning the rules of youth soccer (Wilkinson, 1997). The soccer academies were set up to operate at every age level from under 9 years to under 21 years of age, under specific rules and regulations. Some of the most relevant technical regulations are outlined in Table 2.3. Many of the technical rules and regulations introduced were based on findings from the study of successful youth soccer structures in other countries, a summary of which is provided in Table 2.4. In England small sided games (7v7) for players under the age of 11 years are played on smaller pitches (length – 42 m maximum, 25 m minimum; width 25 m maximum, 15 m minimum). The duration of the small sided games has also been reduced, divided into two equal periods (minimum of 4 min and maximum of 15 min).

Table 2.3. Technical regulations for soccer academies (Wilkinson, 1997).

Minimum number of training hours to be provided within the season per week	Under 9-11 years – not less than 3 hours (2 sessions)
	Under 12-16 years – not less than 5 hours (3 sessions)
	Under 17-21 years – not less than 12 hours
Number of games to be played within the season	Under 9-11 years – minimum 24/maximum 30 (all small sided)
	Under 12-16 years – minimum 24/maximum 30
	Under 15-16 years – minimum 24/maximum 36 (including international games)

Table 2.4. Technical structure of soccer academies (Wilkinson, 1997).

Club (Country)	Training hours per week	Number of competitive games per season
Ajax (Holland)	Under 9-14 years – 5 hours (3 sessions) Under 15-16 years – 6.5 hours (4 sessions) Under 17-18 years – 9 hours (6 sessions)	22 22 26
Barcelona (Spain)	Under 10-14 years – 4.5 hours (3 sessions) Under 15-18 years – 6 hours (4 sessions)	30-36 30
Parma (Italy)	Under 10-14 years – 4.5 hours (3 sessions) Under 15-19 years – 8 hours (4 sessions)	18-22 30-36
Inter Milan (Italy)	Under 12-18 years – 5 to 8 hours	26-38
Sao Paolo (Brazil)	Under 12-14 years – 15 hours (5 sessions) Under 15-18 years – 20 hours (5 sessions)	28 36-40

NB. In Holland, Italy, Spain and Norway all competitive games under 12 years of age are small sided (7v7).

Movement characteristics reported for under 15 players during a game appear to differ from those observed in senior players. The movement speed for Japanese under 15 players was found to range between 0.1 and 7.2 $m.s.^{-1}$ with players moving for the majority of the game below 3 $m.s.^{-1}$, with only occasional movements being over 4.0 $m.s.^{-1}$, 70% of the total movement distance being covered at a speed below 4.0 $m.s.^{-1}$ (Miyaghi and Ohashi, 2003). These movement speeds are somewhat lower than those reported for senior players (Bangsbo, 1994a; Luhtanen, 1994).

Capranica and colleagues (2001) performed match analysis on six pre-pubescent soccer players (11 years of age) during an eleven-a-side game on a regular pitch (100 x 65 m) and a seven-a-side game on a smaller pitch (60 x 40 m) (Table 2.5 and Figure 2.2). No significant differences in types of activity between halves or between eleven and seven-a-side were found. In the seven-a-side game, however, running for less than 10 seconds was 10% more frequent than in the eleven-a-side game, suggesting that a pitch with smaller dimensions is from a physical perspective more suitable for younger players whose motor behaviour is for short runs (Capranica et al., 2001). Furthermore, more passes and fewer tackles were noted during the seven-a-side game, suggesting that the smaller number of team members increases the number of times individual players are in possession of the ball. The small sided game therefore may be more beneficial to younger players where the emphasis is based on improving technical ability. In comparison to elite players, pre-pubescent players were shown to perform more running activity (55% vs. 49%) and less walking activity (38% vs. 46%) (Capranica et al., 2001; Mayhew and Wenger, 1985).

Allen and colleagues (1998) evaluated the match demands of 5-a-side on a small pitch (36 x 21 m) in comparison to eleven-a-side on a regular pitch. Results indicated that the total distances covered by collegiate players were similar for the 5 and 11-a-side game conditions, similar to the findings for pre-pubescent players during 7 and 11-a-side game conditions (Capranica et al., 2001). In contrast, the ratio of high intensity to low/moderate intensity work was significantly higher during 5-a-side compared to the eleven-a-side, although as was found with 7-a-side, there was a significant increase in ball contacts during the 5-a-side game conditions (Allen et al., 1998).

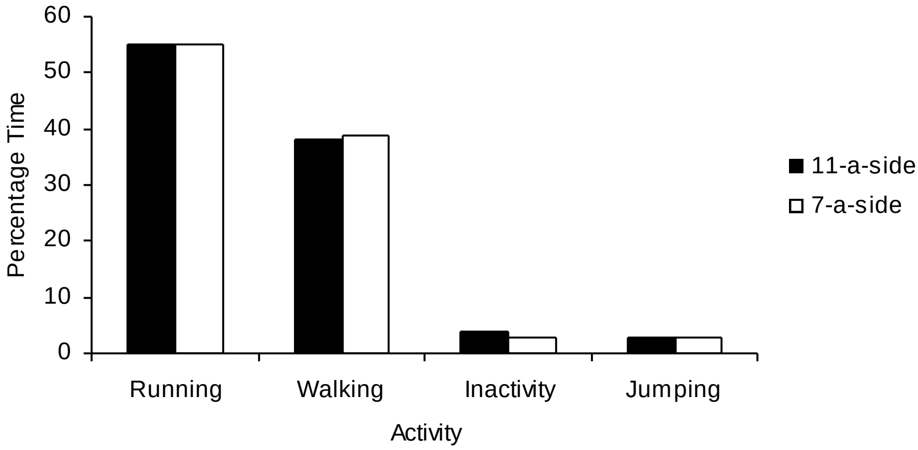


Figure 2.2. Pre-pubescent player activity profiles for eleven-a-side and seven-a-side (Capranica et al., 2001).

Table 2.5. Total time spent running forward, backwards and with the ball during the first and second halves of eleven-a-side and seven-a-side matches for pre-pubescent soccer players (Capranica et al., 2001).

Match	Half	Running forward (s)	Running backward (s)	Running with the ball (s)
Eleven-a-side	First	535 ± 133	19 ± 12	26 ± 19
	Second	646 ± 6	9 ± 4	26 ± 19
Seven-a-side	First	497 ± 153	21 ± 7	29 ± 20
	Second	535 ± 62	24 ± 18	25 ± 10

Stroyer and colleagues (2004) examined activity patterns in young Danish players (12-14 years) with respect to competition level, age and biological maturity. The activity pattern of the elite young players was found to be similar to that reported for elite adult players, whereas the non-elite young players spent less time in low intensity running and more time walking compared to adult players (Table 2.6). The mean duration time of each activity of approximately 6 s observed in the young players corresponds with the early values reported for adult players (Reilly and Thomas, 1976). However, more recent reports of a mean duration time of each activity of 3-4 s for elite adult players (Rienzi et al., 2000; Strudwick and Reilly, 2001) suggests that the adult game is more intensive with more changes in activities taking place over the course of a game. The time motion analysis on the young players also revealed that more time was spent standing still and or walking in the second half compared with the first half, which is comparable with the reduction in exercise intensity reported for adult players during the second half of games (Saltin, 1973; Rienzi et al., 2000; Strudwick and Reilly, 2001; Mohr, Krustrup and Bangsbo, 2003).

Table 2.6. Percentage of total time spent in motion categories during match-play for young players (Stroyer et al., 2004).

	Standing	Walking	Low intensity running	High intensity running	Running total (low and high)
Non-elite players (n=10; 12.1 yrs)	9.6	63.9	19.6	6.8	26.4
Elite players (n=9; 12.6 yrs)	3.6	57.1	31.3	7.9	39.2
Elite players (n=7; 14.0 yrs)	3.1	53.8	34.0	9.0	43.0

2.3 PHYSIOLOGICAL DEMANDS OF SOCCER

2.3.1 Oxygen uptake and relative exercise intensity

Several researchers have examined the aerobic contribution to energy expenditure during soccer through the measurement of oxygen uptake ($\dot{V}O_2$) during game situations (Durnin and Passmore, 1967; Ogushi et al., 1993; Miyagi et al., 1998). However, the collection of heart rate data is less restrictive for players in comparison to expired air samples, and has thus been more widely used (Smodlaka, 1978; Rhode and Espersen, 1988; Van Gool, 1988; Bangsbo, 1994b; Miyagi, 1998). Based on the heart rate values recorded during games it has been suggested that players exercise at an average of approximately 75% of maximal aerobic power ($\dot{V}O_{2max}$) (Ekblom, 1986; Shephard, 1992; Bangsbo, 1994a). Even allowing for overestimations in oxygen uptake due to the indirect nature of calculating oxygen uptake from heart rate Bangsbo (1994b) states that it is reasonable to assume that mean relative exercise intensity in soccer is approximately 70% of $\dot{V}O_{2max}$, underlining the high demands placed on the aerobic energy system (Bangsbo, 1994b).

2.3.2 Sprinting and the anaerobic contribution to energy supply during soccer

Sprinting, jumping, tackling and heading are all activities that primarily stress the anaerobic energy systems. The execution of these high intensity activities is very important as they are the actions that often affect the final outcome of a game, for example, the forward player who out paces a defender to score a goal (Bangsbo, 1994a).

Elite players have been observed to perform approximately 19 sprints during a game, the mean duration of each sprint being ~2.0 s (Bangsbo et al., 1991). Strudwick and Reilly (2001) reported 22 sprints during a game that equates to a maximal effort approximately every 4 min, with an average duration of 3.2±1.6 s for English Premier League players.

2.3.3 Physiological demands of youth soccer

The demands placed on the aerobic and anaerobic energy systems of elite mature players (elite and sub-elite) have been investigated on a number of occasions by analysis of heart rate responses (Reilly and Thomas 1979; Ekblom, 1986; Bangsbo, 1994a). Conversely, very few studies have examined the physiological demands of match-play on young players.

One of the few studies of this nature in young players was conducted by Billows and colleagues (2003), who analysed the physiological strain placed upon adolescent players during competitive match-play. Twenty elite adolescent English academy players (age: 15.5±1.0 years) had their heart rate monitored during a series of competitive games (Table 2.7). The heart rate responses observed in the elite adolescent players were higher than those reported for senior players (Smodlaka, 1978; Rhode and Espersen, 1988; Van Gool et al., 1988; Bangsbo, 1994a), which may be a result of the lower tactical and technical abilities of youth players compared with senior players (Billows et al., 2003). One also needs to take into consideration that sub-maximal heart rate can be 30 beats.min^{-1} higher in young children than in 18 year olds performing the same task (Bar-Or, 1983).

Table 2.7. Heart rate response of elite adolescent players during match-play (Billows et al., 2003).

Heart rate variable	Under 15 years	Under 16 years
Mean heart rate (%HRmax)	87±1.9	84±3.4
1^{st} Half mean heart rate (%HRmax)	87±1.9	84±3.4
2^{nd} Half mean heart rate (%HRmax)	86±2.2	82±4.0
Heart rate range (%HRmax)	71-98	67-96
Mean time <85% HRmax (% playing time)	28	51
Mean time >85% HRmax (% playing time)	72	49

Stroyer and colleagues (2004) measured oxygen uptake ($\dot{V}O_2$) during match-play and noted that elite young players had a higher absolute as well as relative exercise intensity compared to non-elite young players. Furthermore, with regard to playing position, defenders had a lower relative exercise intensity during a game compared with midfielders and forwards (Table 2.8). The specialization due to playing position appears to be more pronounced in the older players (14 years), possibly being an indication of better tactical understanding.

Table 2.8. Maximal oxygen uptake ($\dot{V}O_{2max}$) and match heart rate in relation to playing position for young players during match-play (Stroyer et al., 2004).

	Non-elite players (pre puberty – 12.1±0.7 yrs)	Elite players (pre puberty – 12.6±0.6 yrs)	Elite players (post puberty – 14.0±0.2 yrs)
Defenders	n=7	n=2	N=2
VO_{2max} (ml.min^{-1}.kg^{-1})	57	56	58
Heart rate 1^{st} half (beats.min^{-1})	160	175	169
Heart rate 2^{nd} half (beats.min^{-1})	157	171	168
Midfield/attackers	n=3	n=7	n=5
VO_{2max} (ml.min^{-1}.kg^{-1})	61	59	65
Heart rate 1^{st} half (beats.min^{-1})	166	178	182
Heart rate 2^{nd} half (beats.min^{-1})	158	174	176

2.4 PHYSIOLOGICAL TESTING OF SOCCER PLAYERS

Bangsbo (1994) outlined the importance of obtaining objective information of players' physical performances to plan training programmes, clarify training objectives, identify individual strengths and weaknesses and help motivate players. This importance was highlighted by the fact that 96% of English professional clubs surveyed conducted some form of fitness testing (Erith and Williams, 2005).

Balsom (1994), referred to the need for objective data to monitor changes in performance over time to examine the effectiveness of training and rehabilitation programmes. Furthermore, physical performance test results provide coaches with an insight of individual player adaptations to such training interventions, (MacDougall and Wenger, 1991). It follows that physical performance testing methodologies should be sensitive to change whilst being both valid and reliable (Svensson and Drust, 2005). A valid test should display both logical and construct validity; criterion validity should also be demonstrated for tests where an established 'gold standard' test exists (Strand and Wilson, 1993). Logical validity infers that the test is appropriate to what needs to be measured whilst construct validity relates to whether a test is able to discriminate between different groups of performers (Strand and Wilson, 1993). Reliability of a test refers to consistency or reproducibility of performance when an individual performs the test repeatedly (Hopkins et al., 2001). Tests with poor reliability are unsuitable for tracking changes in performance between trials, and lack the precision to assess performance in a single trial (Hopkins, 2000).

The following sections review commonly used tests in the laboratory and the field that have been used to evaluate physical performance characteristics of soccer players.

2.4.1 Laboratory testing

The majority of energy provision during a soccer game is derived from the aerobic energy system (Bangsbo, 1994b). The assessment of a player's

$\dot{V}O_{2max}$ is therefore important as it underpins performance during a game (Bangsbo, 1994a) and affects recovery between bouts of high intensity exercise (Tomlin and Wenger, 2001). Astrand and Rodahl (1986) define $\dot{V}O_{2max}$ as the maximal amount of oxygen that the body can utilize during exhaustive exercise at sea level. The test used to evaluate an athletes $\dot{V}O_{2max}$ should be similar to the activity of the actual sport (Stromme et al., 1977). Laboratory tests of $\dot{V}O_{2max}$ for soccer players should therefore be performed on a treadmill as opposed to a cycle ergometer to enhance the specificity of the active musculature to that used in the activity patterns of the game itself (Svensson and Drust, 2005). However, Bangsbo and Lindqvist (1992) suggest that $\dot{V}O_{2max}$ is not always a sensitive measure of performance in key aspects of soccer match-play. Despite this, Hoff and colleagues (2002) found $\dot{V}O_{2max}$ to be sensitive to soccer specific endurance training programmes. Similarly, Svensson and Drust (2005) surmise that $\dot{V}O_{2max}$ can be used to monitor improvements in training, differentiate players of different abilities and playing positions.

Activities that take place during a game, for example accelerations and decelerations, place significant stress on the lower limbs, highlighting the importance of strength development in soccer players (Reilly and Doran, 2003). Bell and Wenger (1992) define muscle strength as the amount of force or tension that a muscle or muscle group exerts against a resistance at a specified velocity during a maximal voluntary contraction. In the laboratory setting, isokinetic dynamometry has been used extensively to assess neuromuscular performance (Baltzopoulos and Gleeson, 2001).

A number of limitations relating to the methodology of isokinetic assessments have been highlighted. Assessments are limited to isolated muscle groups, reducing the validity in terms of functional performance where multi-joint movements are the norm (Kannus, 1994). Other potential limitations include the expensive and time consuming nature of isokinetic assessments, especially where whole squads of players are to be tested (Svensson and Drust, 2005). In a recent review by Stolen and colleagues (2005) it was concluded that isokinetic tests do not reflect the movement of the limbs involved during soccer as no natural muscle movement is isokinetic. Wisloff and colleagues (1998) suggest that free body mass tests of functional strength may be most relevant in a soccer context, however such assessments are not as easy to control and can carry a higher risk of injury.

The main benefit associated with laboratory tests is the controlled environment in which they are undertaken, reducing any impact of extraneous variables (MacDougall and Wenger, 1991). Drawbacks related to such tests include, access to suitable laboratory facilities, expense of testing sessions, time-consuming nature of tests, and numerous testing sessions in order to familiarise players with the environment and protocols to obtain reliable results (Svensson and Drust, 2005).

2.4.2 Field testing

Laboratory testing has the advantage of taking place in a controlled environment, whereas field-based tests boast greater specificity and validity (MacDougall and Wenger, 1991). The multi-stage fitness test (MSFT) validated by Ramsbottom and colleagues (1988) has been used in numerous studies to estimate $\dot{V}O_{2max}$ in soccer players (Davis et al., 1992; Tumilty, 2000; Strudwick et al., 2002; Erith and Williams, 2005). The MSFT requires players to complete as many 20 m shuttle runs as possible at a progressively increasing running speed dictated by an auditory signal. Ramsbottom and colleagues (1988) reported a significant correlation (r=0.92) between direct treadmill measurements of $\dot{V}O_{2max}$ and MSFT performance. An advantage of the MSFT is that it allows more than one player to be assessed during a single session (Svensson and Drust, 2005). However, some authors have expressed concerns that $\dot{V}O_{2max}$ predicted from MSFT performance may underestimate actual values (Sproule et al., 1993; St Clair-Gibson et al., 1998).

The ability to accelerate over short distances is an important attribute in soccer players. It has been reported that 96% of sprint bouts in a game are less than 30 m, with 49% being less than 10 m (Valquer et al., 1998). Based on such reports sprint tests of 10, 20 and 30 m have typically been used to assess players' sprint ability (Kollath and Quade, 1993; Strudwick et al., 2002; Hulse et al., 2005). Sprint test protocols include stationary and 'flying' starts (Dawson, 2003). Svensson and Drust (2005) suggest that a 'flying' start is more realistic and valid as the majority of sprints during a game are preceded by a walk, jog or a stride.

Rapid and frequent changes in direction are a common feature of modern day soccer. At present, no agreement on a precise definition of agility within the sports science community exists (Sheppard and Young, 2006). Agility has been described previously as the ability to rapidly change the direction of the body, being a combination of speed, strength, balance and coordination (Draper and Lancaster, 1985). Agility performance does not appear to be closely linked with straight speed components (Buttifant et al., 1999). In the past the 'Illinois agility run' (Cureton, 1951) was considered a standard test of agility (Figure 2.3). Draper and Lancaster, (1985) suggested that the '505' test (Figure 2.4) was more valid as a test of agility. The authors' held the view that agility tests should be independent of top speed, and correlate more with acceleration which is related to the demands of changing direction and re-acceleration. The '505' test was based on the demands of cricket, the movement patterns being similar to those used by batsman running between the wickets. Another popular test of agility is the 'T-Test' (Figure 2.5) which evaluates the ability to change direction rapidly whilst maintaining balance without loss of speed (Semenick, 1990). The 'T-Test' has been described as a valid and reliable measure of agility which may be used to differentiate between those of low and high levels of sports participation (Pauole et al., 2000).

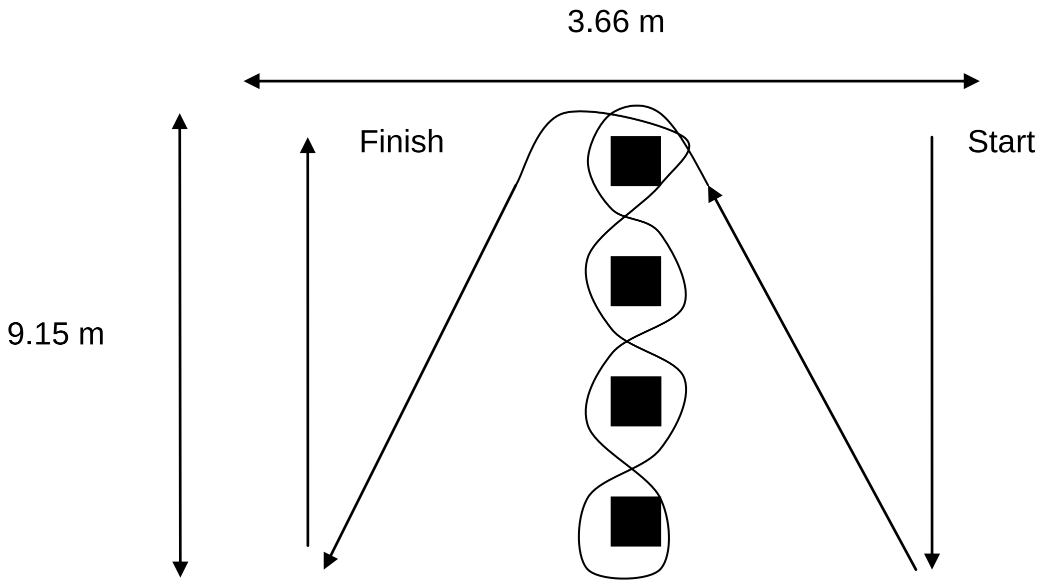


Figure 2.3. Illinois agility run (after Cureton, 1951).

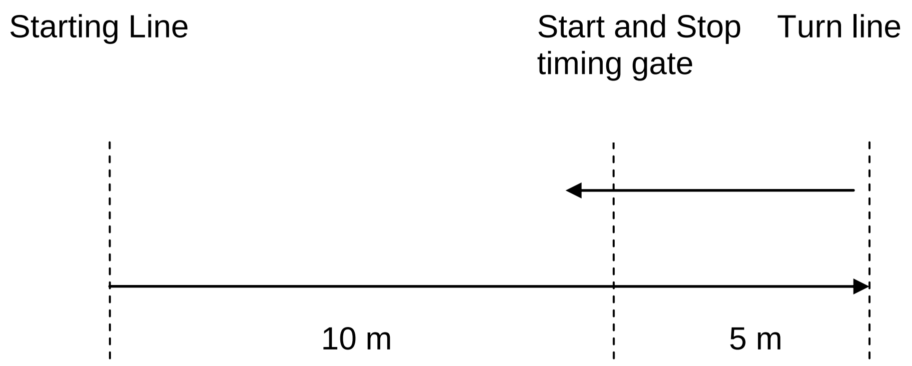


Figure 2.4. The 505 test of agility (after Draper and Lancaster, 1985).

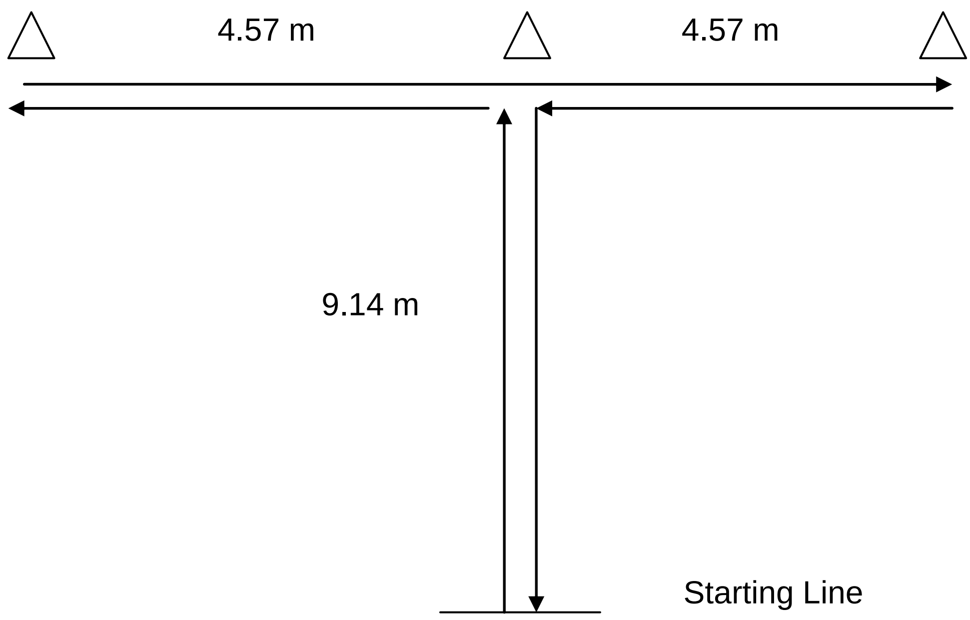


Figure 2.5. The T-test of agility (after Semenick, 1990).

Agility tests, such as those described have been suggested to discriminate elite soccer players from the general population more than any other field test for strength, power or flexibility (Reilly et al., 2000), but at present no 'gold standard' test of agility exists. Despite this, agility performance is viewed as an important component of physiological assessment in soccer (Svensson and Drust, 2005).

Despite the endurance nature of soccer, some authors have suggested that different standards of player (Tumilty, 1993) and different playing positions (Davis and Brewer, 1992) are better differentiated by components of speed, power and strength. As far back as 1921 a standing vertical jump test was introduced which was intended to be a measure of general physical performance (Sargent, 1921). More recently considerable research on the standing vertical jump has been undertaken that supports its multifactorial nature, being related to maximum strength and muscular power of the leg extensor muscles (Young et al., 2001). The vertical jump has been assessed

with an arm swing and with the arm action restricted to evaluate the contribution of the arms (Harman et al., 1990).
Two vertical jump tests, the squat jump (SJ) and the countermovement jump (CMJ) have received most attention from researchers because of the possibility to discriminate between concentric muscle action of the leg extensors and the effect of pre-stretch (Markovic et al., 2004). The authors suggest that the CMJ and SJ, measured by means of contact mat and digital timer, are the most reliable and valid field tests for estimation of explosive power of the lower limbs in physically active men.

Although field tests may be less accurate in comparison to laboratory based measurements they are by their nature more specific (MacDougall and Wenger, 1991). In a recent survey of English professional clubs field tests were found to be more frequently used than laboratory based measures, the most popular tests being sprint and vertical jump tests (Erith and Williams, 2005). Svensson and Drust (2005) suggested that sports scientists can use field tests to evaluate specific aspects of soccer performance, which may provide a better indication of the ability to perform in a soccer match than laboratory based assessments. Furthermore, field tests require only basic equipment, can be performed with relative ease, are relatively cost effective and are less time consuming. The limitation of physical performance tests is that they are not likely to predict overall performance during a game because of the complex nature of the demands of soccer (Svensson and Drust, 2005).

2.5 PHYSICAL AND PHYSIOLOGICAL PROFILE OF SOCCER PLAYERS

Descriptive reports of players' physical and physiological characteristics provide an insight of the 'ideal' make up of an elite player. Studies that have established the functional capabilities of soccer players also enable us to construct a more complete picture of the physiological demands imposed by the game of soccer.

2.5.1 Age and date of birth

The majority of professional soccer players are found to be aged 20 to 30 years. Bangsbo (1994a) reported an average age of 24.0 years (range, 18-36 years) for players in the Danish first division, with a tendency for goalkeepers to be slightly older. It has been suggested that goalkeepers have longer careers than outfield players, possibly because they are less vulnerable to injuries, and because of the importance of experience in this playing position (Reilly, 1994c). However, an investigation of players' ages from the four major soccer leagues in Europe by Bloomfield and colleagues (2003) found no significant differences to exist between the players ages in the respective leagues and/or playing positions (Table 2.9).

Table 2.9. Players' age in the four major European leagues (Bloomfield et al., 2003).

League and playing position	Age (years±SD)	League and playing position	Age (years±SD)
English Premier League:		Italian Seria A:	
Goalkeeper (n=68)	28.2±5.5	Goalkeeper (n=60)	27.2±6.0
Defender (n=185)	26.7±4.6	Defender (n=163)	26.9±4.2
Midfielder (n=202)	25.6±4.6	Midfielder (n=180)	26.2±3.8
Forward (n=123)	25.6±4.8	Forward (n=96)	25.3±4.4
Total (n=578)	26.3±4.8	Total (n=499)	26.4±4.4
Spanish La Liga:		German Bundesliga:	
Goalkeeper (n=56)	27.3±4.0	Goalkeeper (n=50)	26.9±5.5
Defender (n=167)	27.0±4.0	Defender (n=150)	26.5±4.2
Midfielder (n=201)	26.4±4.2	Midfielder (n=164)	26.7±4.5
Forward (n=104)	25.6±3.4	Forward (n=116)	26.6±4.2
Total (n=528)	26.5±4.0	Total (n=480)	26.6±4.4

A number of studies have shown that a player's date of birth is an important factor influencing the chances of a young player being selected for a team and training programme in soccer (Dudink, 1994; Baxter-Jones et al., 1995; Brewer et al., 1995; Musch and Hay, 1999; Helsen et al., 2000; Simmons and Paull, 2001; Gil et al., 2003). Dudink (1994) suggested a 'season-of-birth bias', with Dutch and English players born early in the competition year being more likely to participate in national soccer leagues. The competition year refers to the dates set that determine age group categories of players. For example, the competition year for Football Association (FA) governed English

Soccer Academies is from 1st September to 31st August, whereas the competition year for international soccer under the rules and regulations of the Union of European Football Associations (UEFA) is from 1st January to 31st December. The notion of a 'season-of-birth bias' whereby greater numbers of players born early in a selection year are over-represented in junior and senior elite squads compared with what might be expected based on national birth rates is supported by Brewer and colleagues (1995) and Simmons and Paull (2001), (Table 2.10).

Table 2.10. 'Season-of-birth bias' in association football (Brewer et al., 1995; Simmons and Paull, 2001).

Study population	Oldest 4 months (%)	Intermediate 4 months (%)	Youngest 4 months (%)
Brewer et al. (1995)			
Swedish U17s (n=59)	62.7	25.5	11.8
*Sweden senior players (n=16)	62.6	18.7	18.7
English F.A. School players (n=103)	71.8	23.4	3.8
English F.A. Centre of Excellence players (n=805)	58.7	28.6	12.7
*English professional players (n=1722)	45.6	31.2	23.2
Simmons and Paull (2001)			
English F.A. National School (n=79)	75	19	6
English F.A. Centres of Excellence players (n=8857)	61	28	11
English Schools F.A. players (n=78)	72	22	6
England youth players (n=64)	50	14	36

* No age band category, figures provided are based on junior age band dates.

The concept of a 'season of birth bias' has also been referred to in the literature as a 'relative age effect'. A number of studies have demonstrated the existence of a 'relative age effect' in other sports, including, ice hockey (Boucher and Mutimer, 1994), tennis (Edgar and O'Donoghue, 2005) and baseball (Thompson et al.,1991), (Table 2.11).

Table 2.11. Summary of research investigating 'Relative Age' effect in other sports.

Study	Sport	Subjects	Percentage of performers in each ¼ of selection year			
			Q1	Q2	Q3	Q4
Thompson et al. (1991)	Baseball	1985: 682 adult Major League players	29	27	23	21
		1990: 837 adult Major League players	29	25	23	22
Boucher and Mutimer (1994)	Ice Hockey	1988-89 season: 951 junior players (8-17 years)	37	28	23	12
		1988-89 season: 884 adult NHL players	34	31	20	15
Edgar and O'Donoghue (2005)	Tennis	2002-03: 237 adult male grand slam entrants	29	29	25	17
		2003: 237 elite junior men	33	30	22	15

Despite a large amount of research evidence demonstrating the existence of a 'relative age effect', little of this research conclusively shows why this effect exists (Morris and Nevill, 2007). In a recent review of the literature Morris and Nevill (2007) hypothesize that the relative age effect may occur because, children and young people with birth dates early in a selection period are those who are most likely to be more mature and therefore stronger and faster and have more developed motor and co-ordination skills. As a result, the authors suggest that during selection trials they are the performers most likely to catch the eye especially against age disadvantaged peers. To compound the problem it can be argued that talent selection procedures in many sports focus largely on physiological superiority (Morris and Nevill, 2007).

Contact sports that are chronologically age-group determined are always likely to have participants who are above average in terms of maturity (Malina et al., 1982). A study of Italian youth players suggests a tendency for the selection of those who are advanced in terms of sexual development (Cacciari et al., 1990). Brewer and colleagues (1995) suggested that selected players were always above average in terms of physical maturity, being significantly heavier and taller, therefore contributing to their selection as elite players. Similarly, Helsen and colleagues (2000) argued that current selection programmes are significantly influenced by a child's physical attributes rather than by their sports skills. These findings are supported by the observations that biological maturity (stage of maturation) is a better predictor of performance than chronological age, especially for sports in which physical power is seen as an advantage (Beunen, 1989).

Selection of the older more physically advanced players has been linked to a 'cascade effect', whereby an increased 'season-of-birth bias' is observed as the standard/level of playing increases (Simmons and Paull, 2001). In relation to this effect, Dudink (1994) suggested that being selected at an early age increases an individual's chance of selection in later years by the process of recognition, advanced training and experience in higher levels of competition. Similarly, Thompson and colleagues (1991) note that once an age-advantaged performer has been 'selected' they are likely to be provided with better coaching and higher levels of competition. Thompson and colleagues (1991) go on to suggest that while the skills and self-confidence of the age-advantaged performer develops, their age-disadvantaged peer may experience lack of opportunity, discouragement and possibly disillusionment, perhaps eventually leading to dropout. Such views are supported by Stroyer and colleagues, 2004) who observed significant differences in the match activity profiles of elite and non-elite young players (12 years). Stroyer and colleagues (2004) suggested that after several years playing at a lower level, any subsequent step-up to a higher level is made more difficult, as the player in question will not have been stimulated physically to the same degree as those who have played at the elite level from an early age. This factor is further compounded when one considers that exercise intensity during adolescence may be an important stimulus for the maximal attainable aerobic power (Rodhe and Espersen, 1988).

Fundamentally it is the philosophy of the selection strategy that determines the severity of the 'season-of-birth bias'. If the strategy is based on winning games the older and physically bigger will be chosen, whereas a strategy focused on long-term player development is likely to include more of the younger, less physically advanced players (Simmons and Paull, 2001). Whilst a 'season-of-birth bias' may be advantageous to those born early in junior competition years, it may also be to the detriment of the national team in the long-term as talented and potentially world class players may be disadvantaged (O'Donoghue and Edgar, 2003).

2.5.2 Anthropometric characteristics of senior players

Observations on the height and body mass of soccer players indicates that players vary considerably. For example, data from Williams and colleagues (1973) and Bangsbo and Mizuno (1988) indicates that Scottish professionals appeared on average comparably shorter and lighter than Danish internationals, 174.6 vs. 183.0 cm and 96.4 vs. 77.0 kg, respectively. Such differences may be representative of ethnic and cultural influences. This is highlighted by the large variation in players height and body mass reported by studies on different leagues throughout the world (Table 2.12).

It has been observed that height may influence playing position within a team, with taller players tending to be found in goal and at centre-back, where being tall can be advantageous (Bangsbo, 1994a; Reilly et al., 2000; Matkovic et al., 2003, Isabela et al., 2004; da Silva et al., 2004; Bloomfield et al., 2004; Carvalho et al., 2004), (Table 2.13). Matkovic and colleagues (2003) found that in addition to being the tallest (182.9 $\pm$ 4.3 cm) and heaviest (80.1 $\pm$ 5.1 kg), Croatian goalkeepers also had longer legs and arms ($p<0.05$). In a study of European players, Bloomfield and colleagues (2003) concluded that variations in height and body mass between players in different leagues suggests that the styles of football may vary, with teams from different leagues preferring different types of players in certain positions. Players from the German Bundesliga were found to have the greatest height, body mass and body mass index (BMI) in comparison to top English, Italian and Spanish league players (Bloomfield et al., 2003).

Table 2.12. Summary of studies reporting senior players' height and body mass.

Study	Playing Population	Height (cm)	Body mass (kg)
Raven et al. (1976)	North American Soccer League (n=18)	176.3±1.2	75.7±1.9
Reilly and Thomas (1977)	English 1st Division (n=31)	176.0±6.0	73.2±7.9
Ming-Kai et al. (1992)	Hong Kong 1st Division (n=24)	173.4±4.6	67.7±5.0
Wisloff et al. (1998)	Norwegian 1st Division (n=29)	180.9±4.9	76.9±7.0
Rienzi et al. (2000)	South American Internationals (n=17)	177.0±4.0	74.5±4.4
Al-Hazzaa et al. (2001)	Saudi international players (n=23)	177.2±5.9	73.1±6.8
Cometti et al. (2001)	French 1st Division (n=29)	179.8±4.4	74.5±6.2
Dowson et al. (2002)	New Zealand internationals (n=21)	178.8±6.8	78.9±6.0
Helgerud et al. (2002)	Norwegian 1st Division (n=21)	183.9±5.4	78.4±7.4
Aziz et al. (2003)	Singapore S-League (n=41)	174.0±8.3	70.6±10.3
Bloomfield et al. (2003)	English Premier League (n=578) Spanish La Liga (n=528) Italian Seria A (n=499) German Bundesliga (n=480)	181.0±6.0 180.0±5.0 181.0±5.0 183.0±6.0	75.3±7.3 75.0±5.6 74.3±5.4 77.5±6.4
Matkovic et al. (2003)	1st Croatian National League (n=57)	180.6±5.6	77.6±5.7
Bangsbo et al. (2003)	Danish Premier League (n=47)	179.8±1.0	79.6±1.1
Riach et al. (2003)	Scottish Premier League (n=30)	178.0±6.0	73.9±8.1

Table 2.13. Summary of studies reporting height and body mass of senior players according to positional roles.

Study		Goalkeepers	Central defenders	Full-backs	Midfielders	Forwards
Bangsbo (1994a) (Danish Professionals)	Height (cm)	190.0±0.06 (n=5)	189.0±0.04 (n=13)	179.0±0.06 (n=12)	177.0±0.06 (n=21)	178.0±0.07 (n=14)
	Body mass (kg)	87.8±8.0 (n=5)	87.5±2.5 (n=13)	72.1±10.0 (n=12)	74.0±8.0 (n=21)	73.9±3.1 (n=14)
da Silva et al. (2002) (Brazilian 1st Division)	Height (cm)	185.1±3.6	182.8±3.1		173.1±3.9	178.1±5.9
	Body mass (kg)	79.9±5.9	80.3±4.9		70.4±4.8	72.3±7.1
Carvalho et al. (2004) (Portuguese 2nd Division)	Height (cm)	183.0±0.03 (n=9)	184.0±0.06 (n=13)	173.0±0.05 (n=9)	176.0±0.08 (n=17)	180.0±0.10 (n=11)
	Body mass (kg)	81.5±7.9 (n=9)	82.0±6.2 (n=13)	69.9±6.4 (n=9)	74.3±7.0 (n=17)	78.9±8.6 (n=11)
Bloomfield et al. (2004) (European Premier Leagues)	Height (cm)	187.0±0.04	182.0±0.05		179.0±0.05	181.0±0.06
	Body mass (kg)	82.2±6.2	76.2±5.7		72.9±5.3	75.2±6.2
Isabela et al. (2004) (Brazilian Professionals)	Height (cm)	189.0±0.03	184.0±0.02		169.0±0.2	176.0±0.07
	Body mass (kg)	92.0±1.36	77.0±3.26		73.0±5.49	70.5±3.1

Historically an increase in the size of athletes has been observed in sports where size offers a competitive advantage, for example, rugby union (Olds, 2001). However, when comparing games players with the general population, soccer players were found to be on average similar in height to the general population (Norton and Olds, 2001; Matkovic et al., 2003). In light of the fact that size offers an advantage in certain playing positions (goalkeeper; central defence; central forward) one may expect to see an increase in the size of players, and the suggestion of an increase in players' height has been made by Matkovic and colleagues (2003). At the elite level there does appear to be a trend whereby players are becoming taller and heavier (Table 2.12). For example, the average height and body mass of players in the top division in

England was reported as 176.0 cm and 73.2 kg compared with 181.0 cm and 75.3 kg during the 1976-1977 and 2001-2002 playing seasons, respectively (Reilly and Thomas, 1977; Bloomfield et al., 2003).

Reilly (1990) suggested that the characteristic somatotype of players in general is that of mesomorphy (Table 2.14). It is expected that a muscular build will be of benefit for a number of match activities, the performance of which can often prove decisive in terms of the outcome of a game, for example tackling, accelerating, kicking and shielding the ball. Given the nature of the game, it follows that pronounced muscular development is evident in the lower as opposed to the upper body. This muscular make-up is also displayed in observations of players body composition, with reported values of estimated percentage body fat ranging from 9 to 16% (Reilly, 1990), (Table 2.15). One should note that such values are subject to inter- and intra-individual fluctuations, depending on position (Davis et al., 1992), playing standard, and the time of season (Thomas and Reilly, 1979). Davis and colleagues (1992) found the highest levels of estimated body fat in goalkeepers (13.3 $\pm$ 2.1 %), with lower levels in outfield players (10.5 $\pm$ 1.8 %) for English first and second division players. Thomas and Reilly (1979) reported lower levels of estimated body fat for first team when compared to second team players, with values ranging from 7 to 15 % for professional players (Table 2.15). An investigation into the relationship between anthropometric and work rate profiles of South American international players found a positive relationship to exist between total distance covered and muscle mass, with more muscular individuals being able to maintain a higher overall work rate throughout the game (Rienzi et al., 2000). It is suggested that high degrees of muscle mass along with low levels of body fat reduce the energy requirement of movement, thereby decreasing the physiological load and facilitating recovery from high intensity exercise, resulting in greater distances being covered during the course of a game.

Table 2.14. Summary of studies that have reported the somatotype of senior players.

Study	Playing population	Endomorphy	Mesomorphy	Ectomorphy
Ramadam and Byrd (1987)	Kuwait senior internationals	2.1	4.5	2.1
Apor et al. (1988)	Hungarian elite players	2.1	5.1	2.3
White et al. (1988)	English elite players	3.0	5.0	2.5
Rienzi et al. (2000)	South American internationals	2.2	5.4	2.2

Table 2.15. Summary of studies that have reported the body fat (%) of senior players.

Study	Playing population	Estimated bodyfat (%)
Raven et al. (1976)	North American Soccer League (n=18)	9.6±0.7
Ming-Kai et al. (1992)	Hong Kong 1st Division (n=24)	7.3±3.0
Davis et al. (1992)	English 1st & 2nd Division players (n=135)	11.1±1.9
Rienzi et al. (2000)	South American internationals (n=)	11.6±3.3
Al-Hazzaa et al. (2001)	Saudi international players (n=23)	12.3±2.7
Strudwick et al. (2002)	English Premier league players (n=19)	11.2±1.8
Riach et al. (2003)	Scottish premier league players (n=30)	12.1±2.9
Matkovic et al. (2003)	Croatian elite players (n=57)	14.9±3.5
Aziz et al. (2004)	Singapore S-League players (n=147)	11.0±2.5

2.5.3 Anthropometric characteristics of young players

The anthropometric characteristics of youth players are summarized in Table 2.16. The average height and body mass of young European and North American players (8-14 years) fluctuate above and below reference medians for the general population. Later in adolescence (15+ years) the average height of players is only at or below reference medians, while the average body mass falls above and below the reference median (Malina, 1994). The height and body mass trends for players suggests that players in late adolescence have a greater ratio of body mass to height, a reflection of the mesomorphic physiques reported for players, an example being the Bulgarian junior players studied by Torteva (2002).

Recent studies have examined the anthropometric characteristics of successful and unsuccessful young players (Jankovic et al., 1997; Franks et al., 2002; Gil et al., 2003; Tschopp et al., 2003). Franks and colleagues (2002) analysed 64 English youth international players (14-16 years). The authors found no significant differences in height, body mass or estimated body fat between 'successful' players who went on to secure professional contracts (n=32) and 'unsuccessful' players who did not turn professional (n=32). Similarly, no significant difference was found between elite and non-elite young Danish players (12 years) (Stroyer et al., 2004), (Table 2.18). These findings are not in agreement with findings of Jankovic and colleagues (1993) who studied 16 year old Croatian national players. The authors divided the sample of 47 players into two subgroups, one consisted of the subjects who went on to play in the first team of national league teams and the other of those who were in regional leagues. On comparing the mean values of the subgroups it was found that players involved in the higher level of competition were taller and heavier. Furthermore, studies of Spanish club players (14 years) (Gil et al., 2003), and Swiss national players (U15-U20 years) (Tschopp et al., 2003) also found selected players to be taller and heavier than those players who were not selected.

These findings, which suggest that players who are physically bigger are more likely to be selected and therefore more likely to be successful, are in agreement with related studies that report a selection bias based on date of birth and maturity (Brewer et al., 1995; Helsen et al., 2000; Simmons and Paull, 2001). Large differences in the anthropometric characteristics of young players of the same chronological age are to be expected pre- and post-adolescence because of a difference in the stage of biological maturity. One therefore may expect the more mature players to be in the highest playing levels. However, no differences in skeletal age were found to exist between playing levels for Flemish players (11-12 years), (Janssens et al., 2002). This may however reflect the young age of the players involved, with greater maturational differences being expected during the later stages of adolescence. Cacciari and colleagues (1990) support this suggestion with data from a sample of Italian players (14-16 years), who were found to have an advanced maturity status, indicated by skeletal age, testicular volume and pubic hair development, in comparison to non-athletes.

Table 2.16. Summary of studies that have reported the anthropometric characteristics of young players.

Study	Playing Population	Age (yrs)	Height (cm)	Body mass (kg)	Estimated body fat (%)	Somatotype
Jankovic et al. (1993)	Croatian junior players (n=47)	16.0±0.5	175.7±5.2	66.2±5.6	/	/
Garganta et al., (1993)	Portuguese internationals (n=13)	17.5±0.6	174.3±5.9	72.1±6.1	11.3	3.0-4.0-1.8
Malina et al. (2000)	Portuguese junior players (n=135)	12.3±0.5	151.0±0.1	43.1±7.0	/	/
		13.7±0.7	163.0±0.1	52.5±8.7	/	/
		15.7±0.4	174.0±0.1	64.1±5.3	/	/
		16.1±0.2	172.0±0.1	70.0±8.7	/	/
Helgerud et al. (2001)	Norwegian junior men (n=19)	18.1±0.8	181.3±5.6	72.2±11.1	/	/
Dowson et al. (2002)	New Zealand internationals (n=104)	U15	168.6±8.6	58.3±8.9	/	/
		U17	175.1±5.8	69.9±6.6	/	/
		U19	/	70.7±6.8	/	/
Janssens et al. (2002)	Flemish youth players (n=165)	12.2±0.7	150.7±7.6	40.1±7.0	/	2.4-4.0-3.8
Toteva (2002)	Bulgarian junior players (n=80)	12.0	158.1±10.1	44.1±8.1	/	1.9-4.5-4.3
		13.0	165.9±5.3	52.1±6.7	/	1.6-4.7-4.0
		14.0	166.6±6.5	57.0±8.6	/	2.1-4.9-3.2
		15.0	174.1±3.6	66.3±5.1	/	2.3-5.1-3.0
		16.0	176.1±4.5	69.0±7.1	/	2.4-4.9-3.2
		17.0	174.9±5.1	66.5±6.8	/	2.3-4.9-3.3
Bunc et al. (2003)	Czech junior players (n=28)	10.1±0.4	142.4±5.4	39.9±4.3	16.8±1.1	/
Capela et al. (2003)	Portuguese junior players (n=62)	13.6±0.2	162.2±8.5	53.4±9.7	/	/
		14.6±0.2	168.6±10.7	59.1±10.7		

		15.5±0.3	175.2±6.1	67.3±4.7		
Chibane et al. (2003)	Algerian international players (n=25)	16.0±0.5	175.6±6.7	68.6±7.8	/	2.9-3.4-2.9
DeMello et al. (2003)	American varsity players (n=35)	15.6±1.0	169.2±8.9	60.0±8.6	/	/
Neto et al. (2003)	Brazilian junior players (n=35)	18.1±0.8	177.1±5.7	70.6±7.8	/	/
Tschopp et al. (2003)	Swiss international players (n=48)	15.0±0.3 16.8±0.2 18.9±0.8	171.9±6.4 176.9±6.0 179.1±5.7	62.3±8.0 68.5±6.2 73.9±6.5	/	/
Stroyer et al. (2004)	Elite Danish players (n=16)	12.6±0.6 14.0±0.2	154.1±8.2 172.2±6.1	42.5±7.2 57.5±7.2	/	/
Stroyer et al. (2004)	Non-elite Danish players (n=10)	12.1±0.7	153.1±5.1	40.6±6.6	/	/
Gissis et al. (2006)	Greek elite players (n=18)	16.3±1.3	169.1±5.7	68.2±6.9	/	/
Mujika et al. (2009)	Spanish junior players	18.4±0.9	178.0±5.0	72.0±4.6	/	/

2.5.4 Maximum oxygen uptake ($\dot{V}O_{2max}$) of senior soccer players

The $\dot{V}O_{2max}$ of senior male out-field soccer players varies from approximately 50-75 ml.kg^{-1}.min^{-1}, with goalkeepers possessing lower values of 50-55 ml.kg^{-1}.min^{-1} (Stolen et al., 2005). It has been suggested that a minimum $\dot{V}O_{2max}$ of 65 ml.kg^{-1}.min^{-1} is desirable for top level senior soccer players (Vanfraechem and Thomas, 1988). Reilly and colleagues (2000) propose an actual threshold of $\dot{V}O_{2max}$ (60 ml.kg^{-1}.min^{-1}) below which an individual senior player is unlikely to possess the physiological attributes for success in elite soccer. Furthermore, they advise that this threshold value will need to be increased as training programmes are improved. Related to this, a recent review of the literature has suggested that $\dot{V}O_{2max}$ values of top level senior players has been elevated since the 1980s (Stolen et al., 2005). The same authors maintain that considering the advantages of a high level of $\dot{V}O_{2max}$ in soccer, it would be reasonable to expect a $\dot{V}O_{2max}$ value of 70 ml.kg^{-1}.min^{-1} for professional players. However, although it is believed that a more systematic approach towards the preparation of professional players now exists, higher values of $\dot{V}O_{2max}$ are not always evident (Reilly and Gilbourne, 2003).

A summary of selected $\dot{V}O_{2max}$ data reported for elite senior players in the literature is provided in Table 2.17. From such data it has been suggested that $\dot{V}O_{2max}$ may be used to differentiate between successful and unsuccessful teams, with superior ranked teams in a specific league or teams at a higher level possessing higher levels of $\dot{V}O_{2max}$, (Apor, 1988; Wisloff et al., 1998). Tumilty (1993) has also shown $\dot{V}O_{2max}$ to vary with the standard of competition and the quality of training. Furthermore, $\dot{V}O_{2max}$ has been related to total work done during a game (Hoff et al., 2002) with improvements in $\dot{V}O_{2max}$ being related to an increase in the total distance covered during a game (Helgerud et al., 2001). Allied to this point is evidence that $\dot{V}O_{2max}$ varies depending on a player's positional role within a team. Puga and colleagues (1993) observed that the $\dot{V}O_{2max}$ of 19 senior professional players in the Portuguese First Division was below 60 ml·kg^{-1}·min^{-1} for goalkeepers and central defenders and above 60 ml·kg^{-1}·min^{-1} for midfield players and forwards. These findings are similar to those reported for senior professional players in England where midfield players were found to possess significantly higher $\dot{V}O_{2max}$ values than those of other positions (Reilly, 1990).

The earlier reports of higher $\dot{V}O_{2max}$ values for midfield players are not supported in a more recent study of senior Norwegian professional players (Wisloff et al., 1998). These authors suggested that the observed similarities between positions for $\dot{V}O_{2max}$ may be a result of both higher movement demands of forward and defensive positions in contemporary soccer and the failure of previous studies to apply appropriate scaling for body mass differences. However, as the full body mass must be carried around the field of play in soccer the traditional expression of units for $\dot{V}O_{2max}$ as $ml.kg^{-1}.min^{-1}$ would seem to be the most appropriate.

Table 2.17. Maximal oxygen uptake ($\dot{V}O_{2max}$) of senior soccer players.

Study	Playing Population	n	$\dot{V}O_{2max}$ ($ml.kg^{-1}.min^{-1}$)
Vanfraechem and Tomas (1988)	Division 1/Belgium	18	56.5±7.0
Lindquist and Bangsbo (1993)	National League/Denmark	50	61.2
Puga et al. (1993)	Division 1/Portugal	19	59.6±7.7
Wisloff et al. (1998)	Division 1/Norway (top) Division 2/Norway (bottom)	14 15	67.6±4.0 59.9±4.2
Dowson et al. (1999)	National/New Zealand	25	60.5±2.6
Aziz et al. (2000)	National/Singapore	23	58.2±3.7
Al-Hazzaa et al. (2001)	National/Saudi Arabia	23	56.8±4.8
Matkovic et al. (2003)	Division 1/Croatia	44	52.1±10.7

2.5.5 Power and speed of senior soccer players

A number of studies have reported the vertical jump values of elite senior soccer players as an indication of their lower limb explosive power (Table 2.18). Vertical jump tests have been reported to differentiate between players based on standard of competition (Faina et al., 1988; Gauffin et al., 1989). Senior professional Italian players were found to have higher SJ (+6.2 cm) and CMJ (+6.6 cm) values than their amateur counterparts (Faina et al., 1988). Given the importance placed on explosive power in the modern game, it has been suggested that elite senior players would be expected to have a vertical jump value close to 60 cm (Wisloff et al., 2004). Some authors have noted positional differences in vertical jump height, with goalkeepers having the highest scores whilst midfielders were found to jump lower than the other outfield players (Reilly and Thomas, 1979).

Table 2.18. Vertical jump height of senior players.

Study	Playing Population	n	Jump height (cm)	
			SJ	CMJ
Faina et al. (1988)	Amateurs/Italy	17	34.2	36.9
	Professional/Italy	27	40.4	43.5
White et al. (1988)	Division 1/England	17		59.8
Dowson et al. (1999)	National/New Zealand	25		48.1
Cometti et al. (2001)	Division 1/France	29	38.5	41.6
	Division 2/France	34	33.9	39.7
	Amateur/France	32	39.8	43.9
Jaric et al. (2001)	Division 1/Yugoslavia	20		49.5
Hoff and Helgerud (2002)	Division 2/Norway	8	38.6	44.1
Aziz et al. (2004)	S-League/Singapore	147		58.4
Hoshikawa et al. (2007)	Professional/Japan	30	42.8	57.1
Mujika et al. (2009)	Division 1/Spain	17		50.1

Speed is an essential component in soccer, the ability to accelerate faster than an opponent often deciding the critical aspects of the game. Players must possess the ability to accelerate to meet the physical, tactical and technical demands of the game (Svensson and Drust, 2005). In this context, 10 m sprint performance has been emphasised as a relevant test variable in contemporary soccer (Stolen et al, 2005). A number of studies have reported 10 m sprint performance in elite senior soccer players, with times from 1.72 to 1.90 s being reported in the literature (Table 2.19). Based on these findings the quickest players are on average 1 m ahead of the slowest players after only 10 m of a sprint, which may prove crucial to the outcome of a game (Stolen et al., 2005). Related to this is the observation that senior professional players are faster than amateurs over a 10 m sprint (Kollath and Quade, 1993; Cometti et al., 2001). The relative importance of speed over short distances in modern day soccer is further underlined by the finding that senior amateurs had similar 30 m sprint times to professionals, despite being significantly slower over 10 m (Cometti et al., 2001).

Table 2.19. Sprint performance of senior players.

Study	Playing Population	n	10 m Sprint Performance (s)
Kollath and Quade (1993)	Professional/Germany Amateur/Germany	20 19	1.79±0.09 1.88±0.10
Cometti et al. (2001)	Division 1/France Division 2/France Amateur/France	29 34 32	1.80±0.06 1.82±0.06 1.90±0.08
Wisloff et al. (2004)	Division 1/Norway	17	1.82±0.30
Little and Williams (2003)	Division 1 and 2/England	106	1.83±0.08
Hoshikawa et al. (2007)	Professional/Japan Youth/Japan	30 24	1.72±0.04 1.78±0.04

2.5.6 Maximum oxygen uptake ($\dot{V}O_{2max}$) of young soccer players

The term $\dot{V}O_{2peak}$ rather than $\dot{V}O_{2max}$ is frequently used when referring to children and young adolescents as often these individuals do not reach a plateau in oxygen uptake during tests to determine $\dot{V}O_{2max}$. However, most of the available data on young players refers to 14 to 19 year olds who are physically mature so the term $\dot{V}O_{2max}$ is used throughout this section. Whilst the $\dot{V}O_{2max}$ of male senior players has been thoroughly described relatively fewer studies have reported data on elite youth soccer players (Chamari et al., 2005). Traditionally it has been suggested that young soccer players have lower $\dot{V}O_{2max}$ (<60 $ml.kg^{-1}.min^{-1}$) than seniors although some exceptions may exist (Stolen et al., 2005) (Table 2.20). Apor (1988) reported an average $\dot{V}O_{2max}$ of 73.9 $ml.kg^{-1}.min^{-1}$ for the Hungarian U18 national team, however it should be noted that only 8 players were tested. More recently, McMillan and colleagues (2005) have reported an average $\dot{V}O_{2max}$ of 69.8 $ml.kg^{-1}.min^{-1}$ for elite U17 players in Scotland following 10 weeks of soccer specific endurance training.

Positional differences in $\dot{V}O_{2max}$ have been reported by Stroyer and colleagues (2004) with higher $\dot{V}O_{2max}$ values reported for midfielders/attackers compared with defenders (65.0 vs. 58.0 $ml.kg^{-1}.min^{-1}$, respectively, for elite U15 soccer players). Jones and Helms (1993) reported that $\dot{V}O_{2max}$ was significantly related to sexual maturity based on Tanner's criteria (1962) (Table 2.21). The authors also observed that soccer players $\dot{V}O_{2max}$ was higher to that of the general population at all stages of maturity (Table 2.21). This observation is supported by Leatt, Shephard and Plyley (1987) who reported higher average values of $\dot{V}O_{2max}$ for Canadian U16 and U18 national players compared to the general population (58.3 vs. 49.3 $ml.kg^{-1}.min^{-1}$).

Table 2.20. Maximal oxygen uptake ($\dot{V}O_{2max}$) of young soccer players.

Study	Playing Population	n	$\dot{V}O_{2max}$ ($ml.kg^{-1}.min^{-1}$)
Leatt, Shephard and Plyley (1987)	National U16/Canada	8	59.0±3.2
	National U18/Canada	9	57.7±6.8
Apor (1988)	National U18/Hungary	8	73.9±10.8
Jankovic et al. (1993)	Elite U17/Croatia	47	59.9±6.3
Lindquist and Bangsbo (1993)	Elite U16/Denmark	5	59.5
	Elite U19/Denmark	7	61.3
Dowson et al. (1999)	National U15/New Zealand	56	51.0±4.2
	National U17/New Zealand	23	56.1±5.2
Castagna et al. (2003)	Elite U17/Italy	11	50.0±6.7
Vanderford et al. (2004)	National U14/United States	20	52.9±1.2
	National U15/United States	19	54.5±1.3
	National U16/United States	20	56.2±1.5
Chamari et al. (2004)	National U19/Tunisia	34	61.1±4.6
Chamari et al. (2005)	National U15/Tunisia	21	59.8±5.9
McMillan et al. (2005)	Elite U17/Scotland*	11	63.4±5.6
	Elite U17/Scotland**	11	69.8±6.6

nb. * Before training regimen; ** After training regimen

Table 2.21. Maximal oxygen uptake ($\dot{V}O_{2max}$) with reference to sexual maturity (Jones and Helm, 1993).

Soccer Players					
Sexual Maturity	1	2	3	4	5
N	10	11	7	13	23
Age	12.6±0.1	12.8±0.3	13.7±1.1	14.9±1.2	15.8±1.1
$\dot{V}O_{2max}$ (ml.kg^{-1}.min^{-1})	56.2±3.7	53.7±9.8	55.6±4.7	62.0±6.2	60.2±6.0
General Population (Armstrong et al. 1991, cited in Jones and Helm, 1993)					
N	7	28	13	14	15
Age	11.9±0.8	12.2±0.7	12.9±1.0	14.6±1.0	14.4±1.2
$\dot{V}O_{2max}$ (ml.kg^{-1}.min^{-1})	44.0±7.0	49.0±7.0	46.0±8.0	51.0±6.0	48.0±7.0

2.5.7 Power and speed of young soccer players

The studies that have reported on vertical jump values of elite young soccer players as an indication of their lower limb explosive power have mainly been conducted on players from 14 to 19 years old (Table 2.22). Explosive strength has been described as a key factor in determining jumping and sprinting performance, (Cometti et al., 2001). Esposito and colleagues (2004) suggest that players who display superior speed, agility and strength are likely to be more successful as players. The relative importance of explosive strength for sprint performance has been described by Tscopp and Hubner (2007) in a study of 37 elite Swiss junior players. The authors noted that the fastest players had significantly higher maximal power output relative to body mass in vertical jump (CMJ and SJ) performance, suggesting a higher level of neuromuscular function. The specific development of leg muscle function is considered to be extremely important for elite soccer players (Leatt, Shephard and Plyley, 1987). Leatt, Shephard and Plyley (1987) suggest this to be the reason for the superior vertical jump performance of Canadian junior national players (U16 and U18 years) when compared to the general population.

Merce and colleagues (2007) assessed explosive strength in young Spanish soccer players and established that sprint speed (20 m) and vertical jump (CMJ) performance was significantly better in players of 10-12 years (n=28) than those 8-9 years (n=28). Similarly, better sprint and vertical jump performance was observed in the older players during an assessment of the Belgian junior national teams (U15, U16, U17, U18, U19 years), (Cedric et al., 2007). The authors also noted that the largest improvement in sprint (5 m, 10 m and 20 m) and vertical jump (CMJ and CMJA) performance was evident between the age of 15 and 17 years. Other researchers have advised that the development of running speed accelerates in two phases, firstly at about 8 years and then between 12 and 15 years (Reilly et al., 2000). Reilly and colleagues (2000) suggest that the former improvement is related to the maturation of the nervous system and improved coordination of arm and leg muscles and the latter improvement is related to the increase in body mass and muscle performance. An assessment of sprint velocity in five different age groups of Brazilian players by Dourado and colleagues (2007) supports the observation of improved performance with increasing age over 40 m, however the pattern is less clear over 10 m (Table 2.23). A possible explanation for the lack of improvement in 10 m sprint speed between U14 and U16 years may be the perception of ‘awkwardness’ occurring during this period of adolescence, which is thought to be linked to disproportionate increases in leg length relative to trunk length, (Reilly et al., 2000). However, Beunen and Malina (1988) suggest that only 10-30 % of adolescent boys are affected by such perceived ‘awkwardness’ and the effects are transient.

Table 2.22. Vertical jump height of young players.

Study	Playing Population	n	Jump height (cm)	
			SJ	CMJ
Dowson et al. (1999)	National U15/New Zealand	56		38.0
Luhtanen et al. (2002)	Elite U16/Finland	32		40.4
	Elite U18/Finland	28		42.7
Chamari et al. (2004)	National U19/Tunisia	30	51.3	
Malina et al. (2004)	Elite U14-16/Portuguese	69		29.3
Gissis et al. (2006)	Elite U17/Greek	18	23.6	
	Sub-elite U17/Greek	18	21.4	
	Recreational U17/Greek	18	20.3	
Hoshikawa et al. (2007)	Youth/Japan	24	38.4	50.6

Table 2.23. Sprint velocity in Brazilian soccer players from five different age groups (Dourado et al., 2007).

Age Group	N	10 m Sprint (s)	40 m Sprint (s)
U14	100	1.78±0.2	6.21±0.4
U16	87	1.83±0.4	5.65±0.4
U18	169	1.79±0.1	5.50±0.2
U21	167	1.71±0.1	5.31±0.3
Professionals	230	1.74±0.1	5.31±0.2

Positional differences in sprint speed (30 m) and vertical jump (SJ and CMJ) were not evident in U15 Brazilian soccer players (Neto, Nunes and Hespanhol, 2007). Similarly, Malina and colleagues (2004) found no significant differences to exist in speed (30 m) and power (CMJ) among elite Portuguese junior players (13-15 years). These observations are generally consistent with the limited studies of the functional capacity of small samples of soccer players by position (Malina et al., 2004). However, it should be noted that an earlier study by Sena and colleagues (1997) highlighted that the quickest and slowest young elite Portuguese players (U12-U19 years) were forwards and goalkeepers, respectively.

2.6 GROWTH AND MATURATION OF YOUNG ATHLETES

A number of researchers have evaluated the influence of physical activity on growth, maturity and performance (Sprynarova, 1987; Cacciari et al., 1990; Beunen et al., 1992; Baxter Jones et al., 1994; Hansen et al., 1999). These studies can be categorised into three different approaches:

- investigations into the relationship between physical activity and indicators of growth, maturity and performance,
- comparisons of the characteristics of physically active children and adolescents with those who are inactive, and,
- comparisons of the characteristics of children and adolescent athletes with non-athletes.

2.6.1 Physical activity and stature of young athletes

Data from a longitudinal study by Beunen and colleagues (1992) comparing physically active and inactive Belgian boys from childhood through to adolescence (13 to 18 years of age) indicated no differences in standing height. Active boys were classified as participating in more than 5 hours of physical activity a week, whereas less than 1.5 hours of physical activity a week was classified as inactive. In a longitudinal study on the growth of active and inactive boys, growth and development was not significantly affected by either the nature or the level of the physical activity (Bell, 1993). Regular physical activity however is not in the same category as regular physical training in which many young athletes participate (Malina et al., 2004). For example, elite young soccer players have been observed to train from 5 to 20 hours a week (Wilkinson, 1997), (Table 2.4).

In an early training study on adolescent boys by Ekblom (1969) it was suggested that growth velocity might be accelerated as a result of physical training. However, maturity status was not considered in this study and only a small number of subjects were involved. An additional problem with studies of this nature is that athletes and non-athletes have been compared in order to make inferences about the effects of physical training on growth and development. When differences have been found to exist they have been attributed to the effects of physical training, not taking into account the fact that many young athletes are selected for a particular sport because of their suitable body size (Beunen, 1989). Researchers have attempted to establish whether it is the actual physical activity itself or selection of athletes with a particular characteristic that determines the stature and other physical characteristics of young athletes.

Baxter-Jones and colleagues (1995) compared the physical development of 232 young male athletes (8-19 years) in four different sports (gymnastics; swimming; soccer; and, tennis) for three consecutive years. The process of sports-specific selection was suggested as all the athletes had started training in their respective sports prior to the onset of puberty, with late sexual maturation of gymnasts and early maturation of swimmers being observed. The authors concluded that training did not appear to have affected the young male athlete's growth and development, whilst successful participation in their respective sports was related to inherited genetic traits. Interpretation of these findings is however confounded by the fact that the subjects' initial participation ages ranged between 6.3 and 7.6 years, suggesting that training effects could have occurred prior to the start of the study (Baxter-Jones et al., 1995).

The differences between elite and non-elite young male soccer players were reported in a short longitudinal study by Hansen and colleagues (1999). The elite players were found to be significantly taller compared to the non-elite group and again this was suggested to be a result of selecting the tallest players for the elite group. Similarly, Malina and colleagues (2000) observed that members of the Portuguese national under 16 years team were taller than non-team members, 1.75 ± 0.05 m versus 1.72 ± 0.07 m, respectively ($p=0.10$). The findings from other studies support the observations made by both Hansen and colleagues (1999) and Malina and colleagues (2000), concluding that young soccer players are a selected group in relation to both level of playing performance and stature (Jankovic et al., 1993; Gil et al., 2003; and Tschopp et al., 2003).

Data on the growth and development of young athletes has been compared with reference to standard growth charts (Beunen et al., 1992; Malina, 1994; Baxter-Jones et al., 1995; Malina and Bielicki, 1996; Malina et al., 2000). Malina and Bielicki (1996) compared the growth data for 25 boys who were active in sport to reference data from the Wroclaw Growth Study. The boys who were active in sport were found to be only slightly, but consistently taller than the reference sample during late childhood, with the differences becoming greater during the adolescent growth spurt, 13-16 years. The growth pattern of the active boys was described as being characteristic of early maturers. Baxter-Jones and colleagues (1995) compared the growth and development of male athletes with standard growth charts (Tanner and Whitehouse, 1983). They found that male gymnasts ($n=35$) were below average height for all ages, whilst male swimmers (n=54) and tennis players (n=74) were tall for their age, with mean heights well above the 50th percentile. The soccer players (n=64) were close to average height from 12 to 18 years of age. A limitation of this comparison is that the standard growth charts (Tanner and Whitehouse, 1983) were developed nearly 30 years earlier than the study by Baxter-Jones and colleagues (1995), during which time children were getting larger and attaining maturity at a faster rate (Tanner, 1989). Malina and colleagues (2000) compared the height of 135 elite Portuguese youth soccer players aged 10.7 to 16.5 years with United States reference values for American boys (Hamill et al., 1977 cited in Malina et al., 2000). The mean heights of the soccer players were found to approximate the reference medians.

2.6.2 Body mass, body composition and physique of young athletes

Differences in the body mass of active and inactive boys are generally small and not significant, although reports of heavier inactive compared to active boys may become more apparent during adolescence (Malina et al., 2004). More notably, the level of physical activity has been shown to influence body mass in terms of the proportions of fat free mass and fat mass (Sprynarova, 1987). Sprynarova (1987) compared body mass, fat free mass and percentage body fat of Czechoslovak boys based on their levels of physical activity; active (4 $hours.week^{-1}$ 11 to 15 years of age; 6 $hours.week^{-1}$ 15-18 years of age), moderately active (2 $hours.week^{-1}$ 11-15 years of age; 3 $hours.week^{-1}$ 15-18 years of age), and limitedly active (1 $hour.week^{-1}$ 11-15 years of age or no regular activity 15-18 years of age). The body mass of the active boys was greater than that of boys in the other less active groups from 13 to 18 years of age. Furthermore, the active boys had significantly more fat free mass and less estimated percentage body fat than the moderately and least active boys, particularly in the older boys. Little difference was noted between the moderately and least active boys suggesting that more intensive physical activity is necessary to produce changes in fat free mass during growth.

Bailey and Mirwald (1988) also reported that regular physical training led to an increase in fat free mass and a corresponding decrease in estimated percentage body fat. The estimated percentage body fat values of young athletes have been observed to be lower than those reported for untrained children (Baxter-Jones et al., 1995). Similarly, Hansen and colleagues (1999) found the sum of four skinfolds (biceps, triceps, suprailiac, and subscapular) to be lower in elite (n=48) versus non-elite (n=50) young Danish players (10-12 years). This difference was found to increase over time leading to the suggestion that the more intensive training regimen of the elite players resulted in greater muscle hypertrophy with a corresponding increase in lean body mass, although the more advanced maturity status of the elite players may have been the predominant influence. The suggestions made by Hansen and colleagues (1999), highlight the fact that interpreting the changes in body composition during childhood is complex as the effects of training must be separated from those associated with the normal process of growth and development. Another related issue involves the use of basic formula converting body density to percentage body fat which can lead to an overestimate of percentage body fat in children (Lohman, 1989). This potential limitation was addressed in the study by Baxter-Jones and colleagues (1995) by the use of the equations developed by Slaughter and colleagues (1988) which take into account the effects of both age and sexual maturity on body density.

Baxter-Jones and colleagues (1995) found the body mass of swimmers, soccer players and tennis players to be above reference mean values (Tanner and Whitehouse, 1983). This finding was supported by Malina and colleagues (2000) who found the body mass of elite Portuguese players to be above United States reference medians (Hamill et al., 1977, cited in Malina et al., 2000). The authors noted that this difference was most evident in the two older age groups studied, 13-14 years (n=29) and 15-16 years (n=41). Furthermore, members of the Portuguese national under 16 years team were observed to be heavier than non-team members, 67.5 $\pm$ 6.3 kg versus 63.2 $\pm$ 5.6 kg, respectively (p=0.04). It has been suggested that body mass values above the population mean are a reflection of the athletes' larger stature and increased muscle size (Baxter-Jones et al., 1995). It is widely accepted that training involving persistent muscle use will lead to muscle hypertrophy, and this has been shown to be the case in adolescent athletes (Fournier et al., 1982). However, it should be noted that no direct measurement of muscle mass was made in the study by Baxter-Jones and colleagues (1995). Cacciari and colleagues (1990) found pubertal soccer players aged 12-14 years of age to have lower skinfolds (triceps and subscapular) than an inactive control group. At 14-16 years of age these differences were found to disappear, although the body mass and thigh circumference both significantly increased in the soccer players compared to the control group. These observed differences support the suggestion that physical training can lead to an increase in muscle tissue and a reduction in body fat (Cacciari et al., 1990).

It has been suggested that regular physical activity does not have a significant effect on somatotype during growth (Malina et al., 2004). Carter (1988) performed a comprehensive review of the available data relating to the somatotypes of children and adolescents involved in sports, including, gymnastics, ice hockey, skiing, swimming, athletics, wrestling, tennis and body mass lifting. In general it was found that young athletes in a given sport tend to have somatotypes that are similar to those of adult athletes in the same sport. However, it is suggested that in general young athletes are less mesomorphic, less endomorphic, and more ectomorphic than adult athletes. In the samples of young male athletes reviewed, Carter (1988) noted a tendency for an increase in mesomorphy from mid- to late adolescence into adulthood, a trend that is consistent with non athletic populations. The increased mesomorphy in later adolescence is associated with an increase in testosterone production, which is likely to enhance mesomorphy (Carter, 1988). Some observations of a decrease in mesomorphy in early and mid-adolescence are suggested to be related to the adolescent growth spurt and the consequent increase in ectomorphy (Carter, 1988).

Observations of an elite sample of Portuguese soccer players indicated a trend of more body mass for height (Malina et al., 2000). This was suggested to be consistent with the lower mean ectomorphy of soccer players compared to non-athletic males of the same age. Mean ectomorphy was 3.1 in 11 to 12 year old soccer players compared with 3.7 and 3.8 in 11 and 12 year old non-athletic boys respectively; 3.4 in 13 to 14 year old soccer players compared with 3.9 and 4.1 in 13 and 14 year old non-athletic boys respectively; and 3.0 in 15 to 16 year old soccer players compared with 4.1 and 4.0 in 15 and 16 year old non athletic boys respectively (Hebbelinck et al., 1995, cited in Malina et al., 2000). The mean ectomorphy observed in this sample of young Portuguese soccer players is, on average, consistently higher than that of senior professional soccer players from several European and South American countries (Malina et al., 2000). This observation supports the suggestion of a trend for young athletes to be more ectomorphic than their adult counterparts (Carter, 1988). Furthermore, the ectomorphy of the 15 to 16 year old Portuguese national team members was slightly less than that of non-team members, 2.8 $\pm$ 0.8 versus 3.1 $\pm$ 1.1, respectively ($p>0.05$), being more comparable to that of senior professional players (Malina et al., 2000).

2.6.3 Maturity status of young athletes

The number of studies relating to the effects of physical activity on sexual maturation is quite limited, with the majority focusing on young female athletes and more specifically the age at menarche (Malina et al., 2004). One of the few studies on males was conducted by Bell (1994) who investigated the pubertal characteristics of young Welsh soccer players between the ages of 12.3 and 15.3 years by direct observation of pubic hair. The ages at which the various stages of pubic hair development (Tanner, 1968) were reached did not differ between players of different playing positions or between the players and non-players. Similarly, the length of intervals between stages of pubic hair development did not differ significantly between the players and non-players. The interval between successive stages of pubic hair development was approximately 1.0 year, with 2.5 years between stages two and five for both the players and non-players. The age of the soccer players at 'peak height velocity' (PHV) was 14.2 ± 0.9 years with a PHV of 9.5 ± 1.5 cm.year^{-1}. This was not significantly different to the non-players, and is within the range of PHV values reported for European adolescent athletes (Table 2.24). Bell (1994) concluded that the influence of participation in competitive soccer had no significant effect on the attainment and progress of pubertal development beyond that expected by normal growth. Any conclusions drawn from this particular study must take into account the limitations of the study design. The study ran over a three year period, with the number of subjects involved being fairly small, (22 soccer players and 15 non-players). In an earlier study by Bell (1988) the physiological characteristics of 12 year old soccer players were described. Although the numbers studied again was small (n=18), data for the 12 year old soccer players suggested a maturity associated variation in position, with forwards (n=5) and midfielders (n=4) attaining PHV earlier than defenders (n=7).

Table 2.24. Estimated mean age at peak height velocity (PHV) and peak height velocities (cm.yr^{-1}) in European adolescent athletes in several sports (Adapted from Malina et al., 2004).

Sport	n	Age at PHV (years)	PHV (cm.yr^{-1})
Soccer	8	14.2±0.9	
Basketball and athletics	8	14.1±0.9	10.1±1.2
Cycling	6	12.9±0.4	
Rowing	11	13.5±0.5	
Ice Hockey	16	14.5±1.0	
Ice Hockey	11	12.8±0.5	9.3±3.0
Gymnasts	14	15.0±0.8	7.5±1.1
Gymnasts	11	14.9±0.8	7.4±0.8
Several Sports	21	13.1±1.0	9.3±1.2
Range of means for non-athletes		13.8-14.4	8.2-10.3

Retrospective analysis of longitudinal data from the Wroclaw Growth Study indicated that active Polish boys who were mainly involved in team sports reached the second and fourth stages of pubic hair development (Tanner, 1968) approximately 6 months earlier than the normal population (Malina and Bielicki, 1992). It was also found that the age at which the active boys reached PHV was earlier than that of the normal population, 13.6 ± 0.9 and 14.1 ± 1.1 years, respectively. This is earlier than PHV reported for young Welsh soccer players by Bell (1994). However, such comparisons must take into account the different nationalities of the study populations. Other studies have reported that age at PHV and the magnitude of PHV is not affected by level of physical activity (Mirwald and Bailey, 1986; Sprynarova, 1987; Beunen et al., 1992) (Table 2.25). However, it should be taken into consideration that the methods of classifying an individual as active or inactive do vary between studies.

Table 2.25. Summary of studies estimating mean ages at peak height velocity and peak height velocities ($cm.yr^{-1}$) in active and non-active adolescent boys.

Study	n	Activity status	Age at PHV (years)	PHV ($cm.yr^{-1}$)
Mirwald and Bailey (1986)	14	Active	14.3±1.2	8.7±1.1
	11	Inactive	14.1±0.7	9.9±1.4
Sprynarova (1987)	19	Moderate Active	14.5±1.0	9.7±1.5
	12	Limited active	14.6±1.2	9.8±1.5
Beunen et al. (1992)	32	Active	14.2±0.8	9.4±1.5
	32	Inactive	14.1±0.8	8.9±2.1

Cacciari and colleagues (1990) examined the effect of participation in competitive soccer on growth in 175 Italian players aged 10-16 years in comparison to 224 boys acting as controls. The prepubertal soccer players (10-11.99 years) were not significantly different to the controls in terms of the growth indicators measured. However, pubertal soccer players were significantly taller than controls in the 14-16 years chronological age range. This difference was not significant however when the subjects were compared by bone age. In light of these findings Cacciari and colleagues (1990) suggested that the sample of soccer players was not actually taller, but matured at a faster rate. This suggestion was supported by the finding that the pubertal players (12-16 year olds) were significantly advanced compared to the controls with regard to all indicators of maturity, including, pubic hair development, testicular volume and bone age. It was further suggested that an exercise induced adrenal hyperactivity may have been responsible for the earlier onset of puberty based on higher levels of testosterone and dehydroepiandrosterone (DHEA) in pubertal players compared to non-players (Cacciari et al., 1990). In contrast it could be argued that early maturing boys are preferentially selected for soccer squads at this age (12-16 years).

Increased testosterone levels in boys have been associated with the pubertal growth spurt (Kulin and Muller, 1996). Hansen and colleagues (1999) found higher serum testosterone levels and higher values of testicular volume in elite compared to non-elite young Danish players, indicating that the elite players were more mature. It was also noted that the elite players had trained for 1.9 years longer than non-elite players. Based on these findings Hansen and colleagues (1999) suggested that the higher training and playing level of the elite players could be a stimulus for increasing testosterone concentration and subsequently growth. However, the authors also stated that a bias in the selection process could not be overlooked.

Skeletal maturity has been proposed to be the best method for the assessment of biological maturity status (Malina et al., 2004). Skeletal age is expressed in relation to chronological age, and is often classified in the literature as being advanced, average, or delayed (Malina, 1994). Malina and Bouchard (1991) outlined that the criteria used to define skeletal age categories in the majority of the literature include, advanced (skeletal age is one year or more ahead of chronological age (early maturer)); average (skeletal age is within plus or minus one year of chronological age (average maturer)); and delayed (skeletal age is one year or more behind chronological age (late maturer)).

A longitudinal study of active and inactive 13-18 year old boys by Beunen and colleagues (1992) found no difference in the skeletal age to exist between the two groups. Skeletal age was examined using the carpel x-ray method described by Greulich and Pyle (1959) (cited in Cacciari et al., 1990), in 10-16 year old soccer players and was only found to be advanced in the 14-16 years age group (Cacciari et al., 1990). Similarly, Malina and colleagues (2000) found that skeletal age of the hand and wrist assessed using the Fels method (Roche et al., 1988, cited in Malina et al., 2000), deviated more from chronological age with increasing chronological age in elite Portuguese soccer players. The authors observed that the skeletal age and chronological age were equivalent in the 11 to 12 year old players, whilst mean skeletal age was in advance of chronological age in the 13 to 14 year olds and even further advanced in the 15 to 16 year olds (Table 2.26). More recently Malina and colleagues (2004) have commented that in male athletes, skeletal age and chronological age would appear to display similar increases before the adolescent growth spurt, but suggest that skeletal age progresses at a faster rate than chronological age during the growth spurt and puberty, being reflective of an advanced maturity status in male athletes.

Table 2.26. Distribution of elite Portuguese soccer players by maturity status within chronological age groups (Malina et al., 2000).

Age Group	Maturity Category*			
	Late	Average	Early	Mature
11-12 years (n=63)	13	37	13	0
13-14 years (n=29)	2	16	11	0
15-16 years (n=43)	1	14	21	7

* Late (skeletal age behind or younger than chronological age by more than 1 year); Average (skeletal age within ±1 year of chronological age); Early (skeletal age ahead of or older than chronological age by more than 1 year); Mature (skeletally mature or adult).

A further finding in the study by Malina and colleagues (2000) was that in the younger two age groups studied (11-12 and 13-14 years), players who were advanced in terms of skeletal maturation were taller and heavier ($p<0.02$) and less ectomorphic ($p<0.05$) than those who were late in skeletal maturation (Table 2.27). Observations of this nature would tend to suggest that in the younger age groups, boys at all stages of maturity are represented. However, with advancing chronological age and experience, boys who are advanced in terms of skeletal maturation are more dominant in youth soccer among adolescent players (Malina et al., 2000). It is hypothesised that this may reflect selection or exclusion (self, coach or a combination of both), different success of boys advanced in maturation, the changing nature of the game (more physical contact is permitted in older age groups), or some combination of these factors (Malina et al 2000). Malina and colleagues (2000) concluded that boys who are advanced in terms of biological maturity are successful in soccer in later adolescence, suggesting that the sport of soccer systematically excludes late maturing boys and favours average and early maturing boys as chronological age and sport specialisation increase. Results of this nature published in the scientific literature have raised the question of how to best nurture talented, late maturing boys through developmental programmes without them being systematically excluded. This emphasizes the need for coaches and others involved in youth development programmes to be familiar with the basic principles of growth and maturation.

Table 2.27. Height, body mass and ectomorphy of elite Portuguese soccer players by maturity status within chronological age groups (Malina et al., 2000).

Age Group	Late	Average	Early	Mature
11-12 years	n=13	n=37	n=13	
Height (m)	1.45±0.05	1.51±0.07	1.57±0.05	
Body mass (kg)	38.0±4.6	42.4±6.2	50.2±5.4	
Ectomorphy	3.1±1.0	3.2±0.8	2.6±0.9	
13-14 years	n=2	n=16	n=11	
Height (m)	1.55	1.60±0.06	1.68±0.07	
Body mass (kg)	43.4	48.8±5.5	59.5±8.5	
Ectomorphy	3.7	3.6±0.8	3.0±1.2	
15-16 years	n=1	n=14	n=21	n=7
Height (m)	1.64	1.74±0.04	1.74±0.07	1.72±0.07
Body mass (kg)	57	63.8±4.5	64.7±5.7	70.0±8.7
Ectomorphy	2.6	3.4±0.6	3.1±1.0	2.0±0.6

2.6.4 Peak oxygen uptake ($\dot{V}O_{2peak}$) during growth and maturation

As was briefly discussed earlier, when reporting values of $\dot{V}O_{2max}$ it implies that a plateau in $\dot{V}O_2$ has been demonstrated, however the absence of the $\dot{V}O_2$ plateau at maximal exercise in the majority of children brings into question whether true maximal values are elicited (Armstrong and Welshman, 1994) leading to the suggestion that it was more appropriate to define the highest $\dot{V}O_2$ achieved during a test to voluntary exhaustion as $\dot{V}O_{2peak}$ as opposed to $\dot{V}O_{2max}$ (Rivera-Brown et al., 1995). Based on these observations and the young age of players referred to in this section the term $\dot{V}O_{2peak}$ will be used throughout.

Longitudinal studies have indicated that $\dot{V}O_{2peak}$ ($l.min^{-1}$) in boys increases linearly from the age of 8 to 16 years of age (Armstrong and Welshman, 1994). Krahenbuhl and colleagues (1985) reviewed 68 studies that examined the developmental aspects of $\dot{V}O_{2peak}$ in a total of 5793 males and found absolute increases from approximately 1.0 $l.min^{-1}$ at 6 years of age to 3.2 $l.min^{-1}$ at 16 years of age. This increase has been attributed to dimensional changes in the cardiovascular system that occurs during growth and maturation (Rowland, 1990). Rowland and colleagues (1994) state that the contribution of size-independent functional changes, such as improved myocardial contractility or increased activity of cellular aerobic enzymes is uncertain. Adjusting $\dot{V}O_{2peak}$ values in children is seen as critical when making comparisons between groups, comparing with norms and assessing changes in $\dot{V}O_{2peak}$ of individual subjects over time (Rowland et al., 1994). Longitudinal studies of the relative peak $\dot{V}O_{2peak}$ ($ml.kg^{-1}.min^{-1}$) show that it remains stable in boys from the age of 8 to 16 years of age (Armstrong and Welshman, 1994). A mean relative value of peak $\dot{V}O_{2peak}$ ($ml.kg^{-1}.min^{-1}$) for boys has been reported to remain constant at approximately 53 $ml.kg^{-1}.min^{-1}$, between 6 and 16 years of age (Krahenbuhl et al., 1985).

Malina and colleagues (1997) described the relationship between $\dot{V}O_{2peak}$ ($l.min^{-1}$) and maturation in 47 boys who attended sports schools. The boys were tested annually over a three year period, and were divided into three groups, including, early, average, and late maturers based on the slope of height velocity during the study period. The early maturers demonstrated higher absolute values of $\dot{V}O_{2peak}$ (l.min^{-1}) at all testing sessions. Based on these findings it was suggested that the time pattern, or tempo, of the development of $\dot{V}O_{2peak}$ (l.min^{-1}) during puberty parallels that of sexual maturation (Malina et al., 2001). Beunen and Malina. (1988), reviewed studies that assessed the influence of puberty on $\dot{V}O_{2peak}$ (l.min^{-1}), suggesting several trends and changes in $\dot{V}O_{2peak}$ (l.min^{-1}) relative to the timing of the adolescent growth spurt. One suggestion was that of an adolescent growth spurt in $\dot{V}O_{2peak}$ (l.min^{-1}) which reaches a period of maximum gain near the time of PHV. For example, the maximal increase in $\dot{V}O_{2peak}$ (0.412 l.min^{-1}.yr^{-1}) for Canadian boys was reported to occur in the year of PHV (Mirwald and Bailey, 1986, cited in Beunen and Malina, 1998). Beunen and Malina (1988) also suggested the trend for an increase in absolute $\dot{V}O_{2peak}$ (l.min^{-1}) approximately 5-6 years before PHV in boys which continues to increase throughout the growth spurt in stature. The authors also observed a trend for more variability in values of relative $\dot{V}O_{2peak}$ (ml.kg^{-1}.min^{-1}) after PHV in boys. Observations of this nature suggest that puberty influences improvements in $\dot{V}O_{2peak}$ (l.min^{-1}) by increasing body size, particularly the dimensions of the cardiovascular system (Beunen and Malina, 1988). Other researchers, however, have suggested that improvements in $\dot{V}O_{2peak}$ (l.min^{-1}) during puberty are greater than can be accounted for simply by somatic changes alone (Rowland, 2005).

A longitudinal study conducted by Armstrong and Welshman (2001) assessed changes in $\dot{V}O_{2peak}$ (l.min^{-1}) in children between the ages of 11 and 17 years. Using multilevel regression modelling the authors demonstrated that $\dot{V}O_{2peak}$ (l.min^{-1}) increases between the ages of 11 and 17 years above the effects of body size alone. Armstrong and Welshman (2001) found lean body mass to be the major factor influencing the increase in $\dot{V}O_{2peak}$ (l.min^{-1}), whilst observing no effect of blood haemoglobin concentration on this growth in aerobic fitness. Similarly, Roemmich and Rogol (1995) suggest that longitudinal changes in $\dot{V}O_{2peak}$ (l.min^{-1}) are more closely related to the amount of fat free mass as opposed to body mass. Janz and colleagues (1998) performed a 5 year longitudinal study, scaling values of $\dot{V}O_{2peak}$ (l.min^{-1}) for differences in body size during puberty. It was found that $\dot{V}O_{2peak}$ (l.min^{-1}) increased with stage of sexual maturation even when body mass was considered. However, the authors noted that when lean body mass was substituted for body mass in the analysis, the influence of sexual maturation on the development of $\dot{V}O_{2peak}$ (l.min^{-1}) was eliminated. This observation led to the suggestion that improvements in $\dot{V}O_{2peak}$ (l.min^{-1}) which occurred during puberty and were independent of increases in body mass could be accounted for by changes in body composition (Janz et al., 1998).

Maturation of the pulmonary and cardiovascular systems and peripheral factors (for example, biochemical changes in skeletal muscle tissue) have been shown to coincide with sexual maturation and influence $\dot{V}O_{2peak}$ (l.min^{-1}) (Roemmich and Rogol, 1995). It has been suggested that pulmonary factors do not limit $\dot{V}O_{2peak}$ (l.min^{-1}) during growth, with the level of maximal pulmonary ventilation doubling between 8 years of age and maturity, from approximately 50 l.min^{-1} to 100 l.min^{-1} (Malina et al., 2004). However, data on the longitudinal changes in pulmonary function during childhood and adolescence is understood to be fairly limited (Roemmich and Rogol, 1995). Observations of higher heart rates for children at a particular $\dot{V}O_2$ compared to adults is indicative of diminished cardiac output in children, the result of a lower stroke volume in children (reported resting values of 40 ml.beat^{-1} in preadolescents versus 60 ml.beat^{-1} in adults) (Malina et al., 2004). As a result of such marked differences, Rowland and colleagues (1988) found that physically fit male adults could increase their cardiac output 37% more than children during maximal exercise. This finding corresponded with the adult men's ability to increase their oxygen uptake 34% more than the children (Rowland et al., 1988). A greater arteriovenous oxygen difference during sub-maximal and maximal exercise is one peripheral factor that may influence the $\dot{V}O_{2peak}$ (l.min^{-1}) of children, helping to compensate for their lower levels of cardiac output (Roemmich and Rogol, 1995). Changes in other peripheral factors associated with maturation, including, muscle capillary density, mitochondrial enzyme activity and muscle oxidative potential have received little attention by researchers because of the ethical issues surrounding muscle biopsy studies on children (Roemmich and Rogol, 1995).

2.6.5. Adaptations to endurance training

Training induced adaptations in $\dot{V}O_{2max}$ ($l.min^{-1}$ and $ml.kg^{-1}.min^{-1}$) have been extensively studied in adults, with some practitioners recommending similar training programmes for young people. However, the response of children and adolescents to endurance training is a controversial subject (Baquet et al., 2003). An earlier longitudinal study by Mirwald and colleagues (1981), found that training had no effect on children's $\dot{V}O_{2peak}$ ($l.min^{-1}$) before puberty, suggesting that there is a maturational threshold below which children are not able to increase their $\dot{V}O_{2peak}$ ($l.min^{-1}$). Conversely, other researchers have reported positive training effects in pre-pubertal children (Pate and Ward, 1988; Shephard, 1992). It has been suggested that such discrepancies between studies are, in part, due to different procedures in terms of study protocol design and training methods (Baquet et al., 2003) (Table 2.28). Pate and Ward (1988) identified three physiological characteristics that reflect increased endurance performance in children and young people, including, high levels of $\dot{V}O_{2peak}$ ($l.min^{-1}$), a delayed 'lactate threshold' and an efficient economy of energy expenditure during sub-maximal performance.

Table 2.28. A summary of considerations when interpreting the findings of endurance training studies in young people (Baquet et al., 2003).

Methodological Considerations	• Assessment of maturity status • Subject gender • Subject group constitution (randomised; non-randomised) • Initial $\dot{V}O_{2peak}$ (l.min^{-1}) values of subjects • Physical activity levels of subjects • Consistency between training and testing procedures • Monitoring of training intensity/duration • Subject drop out and attendance
Training Design	• Frequency and duration • Length of programme • Intensity • Type (continuous; intermittent; mixed)

Sjodin and Svedenhag (1992) performed an eight year longitudinal study with eight male runners, examining sub-maximal and maximal responses to exercise over an 8 year period, starting from when the subjects were 12 years of age. Sub-maximal blood lactate concentrations were found to decrease over the course of the study, supporting the suggestion that during adolescence energy expenditure becomes more efficient during sub-maximal exercise. Cureton and colleagues (1997) examined the determinants of the rise in endurance fitness in a cross-sectional study of three groups of children based on chronological age (7 to 10 years, 11 to 14 years, and 15 to 17 years). Time taken to cover one mile on an outdoor track was found to improve by 0.52 min per year, while sub-maximal $\dot{V}O_2$ (8 km.h^{-1} on a treadmill) decreased by 1.0 ml.kg^{-1}.min^{-1} each year and percentage of peak $\dot{V}O_2$ increased by 1.5% per year. Analysis of these findings indicated that the rise in percentage of peak $\dot{V}O_2$ and improvements in running economy accounted for 41% and 31%, respectively, of the increase observed in endurance performance (Cureton et al., 1997). In relation to these observations Rowland (2004) suggests that improvements in running economy as children age may be the consequence of a number of factors, including, a progressive decline in the number of strides required to run at a given velocity, an increase in levels of elastic recoil in the leg musculature and a reduction in the level of muscle cocontraction.

The majority of endurance training studies in children and adolescents have focused on changes in peak VO_2 values (Naughton et al., 2000). When only studies showing significant improvements in $\dot{V}O_{2peak}$ ($l.min^{-1}$ and $ml.kg^{-1}.min^{-1}$) are considered, the average improvement was 10.1% for prepubertal and 8.8% for circumpubertal individuals (Rowland, 1985). These figures are somewhat higher than the average 5% improvement in peak VO_2 values during training of preadolescent populations, reported in a review by Payne and Morrow (1993). Furthermore, in a review by Pate and Ward (1996), it was suggested that adaptations to endurance training appeared to be similar before and after puberty but not during it. However, the evidence supporting the suggestion of a decreased sensitivity to training during the pubertal growth spurt is somewhat limited (Naughton et al., 2000). It has been suggested that there is a marked increase in the aerobic trainability of males following puberty (Rowland, 1997). This increase was originally referred to as the 'trigger hypothesis' (Katch, 1983, cited in Rowland, 1997), proposing that the increased potential for aerobic power in more mature males was associated with pubertal changes. It would therefore appear that improvements in $\dot{V}O_{2peak}$ ($l.min^{-1}$ and $ml.kg^{-1}.min^{-1}$) in adolescent males may reflect both maturation and training, however, the mechanisms through which both maturation and training improve endurance performance in adolescent males are not well differentiated (Naughton et al., 2000). In a recent review of endurance training studies in young people Baquet and colleagues (2003) outlined a number of key findings in relation to endurance training programme design, suggesting:

- in prepubertal and circumpubertal children, the gain in $\dot{V}O_{2peak}$ ($l.min^{-1}$) was improved by increasing the number of sessions per week, with 3 to 4 sessions per week of 30 to 60 min being the most effective method to improve $\dot{V}O_{2peak}$ ($l.min^{-1}$),
- the length of a training programme is not a decisive factor in obtaining a significant gain in $\dot{V}O_{2peak}$ ($l.min^{-1}$),

- for the same relative training intensity circumpubertal boys demonstrate higher changes in $\dot{V}O_{2peak}$ (l.min^{-1}) than prepubertal boys,
- for prepubertal boys, ‘all out’ exercises lead to greater improvements in $\dot{V}O_{2peak}$ (l.min^{-1}) than continuous or intermittent exercises,
- in both children and adolescents a training intensity higher than 80% of HR_{max} is necessary to improve $\dot{V}O_{2peak}$ (l.min^{-1}), and,
- both continuous training and interval training can lead to significant improvements in $\dot{V}O_{2peak}$ (l.min^{-1}) in young people.

2.6.6. Power and sprint performance during growth and maturation

A linear rate of increase in power of boys (measured in a 10 s maximal ergocycle test) during childhood is reported up to the onset of puberty, after which power is observed to increase at a faster rate up until approximately 19 years of age (Malina and Bouchard, 1991). Van Praagh (2000) observed that most of the studies describing the effects of growth on power are cross-sectional as opposed to longitudinal, although all suggest a significant increase of power (absolute or relative values) with chronological age or maturity status.

De Ste Croix and colleagues (2001) demonstrated that the development of thigh muscle volume made a significant contribution to short-term power output measured during a 30 second Wingate test on a cycle ergometer. This finding supports the observation made by Blimkie and Sale (1998) that muscle cross-sectional area is the most important factor influencing muscle force during growth. Power has been shown to increase with age in children even when it is corrected for fat free mass or muscle size of the active limb, suggesting that factors other than increased musculature enhance the power at puberty (Falk and Bar-Or, 1993). Ferretti and colleagues (1994) investigated changes in peak jumping power using a force platform with 13 children aged 8 to 13 years of age and compared them with 10 adults aged 20 to 35 years. The peak values were 65% lower in the children, whereas muscle cross-sectional area determined by means of anthropometry was 45% less in the children compared to the adults. The authors suggested that part of the unexplained difference in peak jumping power between children and adults was associated with hormonal changes occurring during puberty. This suggestion was based on the hypothesis that the increase in muscular force with growth occurs in parallel with muscle cross-sectional area increases before puberty, while the increase in force is greater than that in muscle cross-sectional area after puberty because of selective hypertrophy of type II muscle fibres induced by testosterone secretion (Ferretti et al., 1994). Furthermore, there is evidence that children have a higher percentage of type I fibres and lower percentage of type II fibres compared with adolescents and adults (Van Praagh and Dore, 2002). Van Praagh (2000) suggests that older children have an advantage over younger children in high speed strength and power activities as a result of the increase in type II fibre type distribution with increasing age.

Neural factors have also been suggested to promote the enhanced power associated with maturation. Sale (1994) suggests that increased coordination of the muscle synergists and antagonists, along with an increased ability to activate the working muscles occurs during maturation. The suggestion that part of the increase in muscle force is attributed to improved motor coordination, is thought to be of particular importance when interpreting muscle force improvements in more complex, multi-joint exercises, for example vertical jump, cycling, and sprint running tests (Van Praagh and Dore, 2002). Similarly, Sargeant (1998), refers to a ‘neural learning’ effect whereby the pattern of muscular recruitment is improved.

2.6.7. Adaptations to power and sprint training

The trainability of short term muscle power is observed to increase markedly during puberty (Blimkie and Sale, 1998). Van Praagh and Dore (2002) suggest that the most plausible explanation of this observed increase is the ‘trigger hypothesis’, linking the increase of short-term muscle power during adolescence with hormonal changes and marked growth and maturation of the neuromuscular system.

Fournier and colleagues (1982) conducted a sprint training study with 16 to 17 year old boys, examining alterations in muscle phosphofructokinase (PFK) and fibre area. The sprint training consisted of interval runs varying from 50 m to 250 m, four times a week for three months. A 21% increase in PFK activity and 10% increase in $\dot{V}O_{2max}$ was observed, although no change was found in muscle fibre size or distribution. A subsequent biopsy taken 6 months after the cessation of the study indicated that the activity of PFK had returned to the pre-training levels, which were less than observed in adults (Fournier et al., 1982). A more recent study by Diallo and colleagues (1999a), confirmed that plyometric and cycle sprint training improves countermovement jumping performance and sprint cycling performance in prepubertal male soccer players. Thirty 12 to 13 year olds were divided into three groups, a plyometric training group, a cycle sprint training group, and a non-training control group. The training was conducted three times a week over a ten week period. The countermovement jump height and sprint cycling performance of both the jump trained and sprint cycle trained boys improved significantly in comparison with the non-trained controls. No muscle hypertrophy was evident as a result of the training, the authors suggesting that the improved performance was due to neural factors. Interestingly, no decrements in performance were observed when the subjects were tested again following an eight week detraining period (Diallo et al., 1999b).

Power and/or sprint training has not been examined through different pubertal stages. Rowland (2005) refers to the inherent difficulties in such training studies, including, a lack of agreement on what denotes power/sprint training, the complex masking effects of hormonal factors with training responses during puberty and difficulties in matching exercise and control groups.

2.6.8. Ethnic variation in growth, maturation and physical performance

The terms ethnic and racial are related but have different meanings. Race implies a biologically distinct group that has a relatively large percentage of its genes in common by descent. Ethnic implies a culturally distinct group. Historically racial and ethnic background has been defined by skin colour (i.e.

Whites, Blacks) and geographic origin (ie. Black African, Black Caribbean). Throughout the thesis the term ethnic is used, whilst recognizing the complexities of issues related to the concept.

Information from a number of national surveys has indicated that on average the stature of Black children is slightly greater than in White children (Malina, Bouchard and Bar-Or, 2004). Ethnic variations in body proportions have been observed in studies of the sitting height and standing height ratio. A study of American boys by Martorell and colleagues (1988) suggested that for the same standing height Black children have relatively shorter trunks and longer lower extremities than White children. In addition to proportional differences in lower extremity length, there is some evidence that Black children have narrower hips relative to the shoulders and relatively longer upper extremities in comparison to White children (Malina, Bouchard and Bar-Or, 2004).

Ethnic variation in the timing of maturation has been investigated in relation to skeletal maturity and secondary sex characteristics. In a study of American children Sun and colleagues (2002) found ages at the onset of secondary sex characteristics to be earlier in Black boys in comparison to White boys. Black American adolescent boys have also been shown to attain peak height velocity (PHV) at an earlier age than American White adolescents, 13.3 years versus 13.6 years, respectively (Berkey, et al., 1994).

The study of ethnic variation in physical performance has received little attention in comparison to corresponding studies on growth and maturation (Malina, Bouchard and Bar-Or, 2004). It has been suggested that Black children are generally advanced in terms of motor development during the first two years of life, and that Black children of school age perform consistently better than White children in vertical jump and sprint tests (Malina, 1988). In contrast to the trends suggested for jumping and sprinting performance, comparisons on other tests, including endurance and static strength revealed no consistent differences between Black and White children (Malina, 1988). Environmental factors such as the variation in the nurturing of Black and White children have been put forward as explanations for the better performances of Black children and adolescents in some physical tests (Malina, Bouchard and Bar-Or, 2004).

2.7 SUMMARY

The physiological demands of soccer were investigated at the start of the review. The physiological assessment of soccer players was then discussed, highlighting recognized laboratory and field-based fitness tests and the physical performance profiles that such tests have created in relation to the elite player. Specific consideration throughout the review was given to the young player and the effects of growth and maturation on physical performance.

CHAPTER 3
GENERAL METHODS

3.1 INTRODUCTION

The specific experimental procedures pertaining to each study will be described within the methods section of each study chapter. The methodological procedures that are common to each study are described in this chapter.

The chapter consists of two sub-sections. The first section outlines the questionnaire design, administration and analysis relating to 'Physical Performance in Soccer – Analysis and Measurement'. The second section relates to the physical performance testing research. This includes the preparatory work that was carried out before embarking on the process of data collection. The processes and procedures of ethical approval and participant consent are outlined. The actual process of data collection, including the relevant personal details of the subjects and their physical performances, is discussed.

3.2 QUESTIONNAIRE 'PHYSICAL PERFORMANCE IN SOCCER – ANALYSIS AND MEASUREMENT'

3.2.1 Questionnaire design

The purpose of the 'Physical Performance in Soccer' questionnaire was to investigate the understanding and beliefs of coaches, fitness professionals and players in relation to the physical aspects of performance in soccer. The questionnaire was initially piloted prior to being administered as part of the main study. Twelve people involved with professional soccer, including, 4 coaches, 4 fitness professionals and 4 players completed the questionnaire. Feedback was given on the wording, understanding and layout of the questionnaire, and minor changes were made as a result of the comments received.

The questionnaire was divided into three sections. Demographic information was collected in Part A and was slightly different for the questionnaires administered to coaches, fitness professionals and players, respectively. Coaches provided information relating to their sex, age, position at club, highest coaching qualification and coaching experience (Appendix N). Fitness professionals provided information relating to their sex, age, occupation, professional qualifications, highest coaching qualification and coaching experience (Appendix O). The only demographic information given by players related to their sex, age and highest playing standard (Appendix P). Part B was the same for all questionnaires and concerned opinions on physical performance in soccer. Information was collected in relation to the perceived importance of different physical attributes (strength, endurance, speed, power, speed endurance, balance/co-ordination and agility) with regard to playing position, international soccer, modern day soccer, ethnicity, injuries, playing performance and young players (Appendices N, O and P). Part C was the same for all questionnaires and examined perceptions of physical performance testing, including information on the physical attributes to test, accuracy of objective versus subjective assessments, benefits and the problems associated with physical performance testing (Appendices N, O and P).

3.2.2 Questionnaire administration

The respective questionnaires were administered to coaches, fitness professionals and players during the 2002-2003, 2003-2004 and 2004-2005 playing seasons. The coaches all worked in professional football club academies or centres of excellence on either a full-time or part-time basis and had been in attendance at a Football Association coaching course during the period of data collection. The Fitness Professionals were all members of the Football Association Fitness and Conditioning Forum. The players were from one professional football club academy and three junior international teams.

3.2.3 Questionnaire analysis

Completed questionnaires were coded and the data was entered onto a computer database for analysis. All data were processed using the software SPSS (Version 16.0, Chicago, Illinois, USA).

3.3 PHYSICAL PERFORMANCE TESTING INFORMATION AND SUBJECT DETAILS

3.3.1 Preparatory work

Prior to embarking on the physical performance testing research project some preparatory work was carried out before finalising the physical performance testing protocol that was to form the basis of the data collection procedures. Exercise scientists working in professional football clubs were sent a letter outlining the basis of the proposed research project to be conducted with elite young players (Appendix A). A form was enclosed with the letter to invite specific comments regarding the proposed research project testing protocol (Appendix B). The comments that were returned were then taken into consideration when deciding on the physical performance testing protocol.

3.3.2 Ethical approval and subject consent

Ethical approval was obtained from the Loughborough University Ethical Advisory Committee for all procedures subsequently outlined. Exercise Scientists at each of the clubs involved with the research were informed by letter regarding the issue of player consent to take part in the research project (Appendix C). The parent/guardian of all participating players were given an informatory letter regarding the performance testing project (Appendix D). A brief summary of all the testing procedures was also given to all participating players and their parent/guardian (Appendix E). All participating players over the age of 16 years were asked to sign a consent/disclaimer/release of information form (Appendix F). A parent or guardian of all players under the age of 16 years was asked to sign a separate consent/disclaimer/release of information form (Appendix G).

3.3.3 Subject information and anthropometric measurements

Prior to the start of each testing session a series of personal details and anthropometric measurements were collected from each subject and recorded (Appendix H). The personal details that were collected and the method by which they were recorded is outlined in the following sub-section.

3.3.3.1 Name of subject

The first name and surname of each subject to take part in the testing session was recorded.

3.3.3.2 Date of birth

The date of birth of each subject to take part in the testing session was recorded.

3.3.3.3 Ethnic group

The ethnic group of each subject to take part in the testing session was recorded using the groups listed below. The ethnic groups used were taken from 'The 1991 Census ethnic group question asked in England, Wales and Scotland'.

<u>Ethnic Group Codes</u>

White	- 1
Black Caribbean	- 2
Black African	- 3
Black Other	- 4
Indian	- 5
Pakistani	- 6
Bangladeshi	- 7
Chinese	- 8
Other	- 9

In accordance with the guidelines set out in the 1991 Census, if the subject was descended from more than one ethnic or racial group they were asked to select the group to which they considered they belonged to.

3.3.3.4 Nationality

The nationality of each subject to take part in the testing session was recorded using the codes listed.

<u>Nationality Codes</u>

English	- 1	Danish	12
Welsh	- 2	Norwegian	13
Scottish	- 3	Croatian	14
Northern Irish	- 4	Portuguese	15
Southern Irish	- 5	Belgian	16
French	- 6	Swiss	17
Italian	- 7	Austrian	18
Dutch	- 8	Nigerian	19
German	- 9	Australian	20
Spanish	- 10	Other – (specified)	21
Swedish	- 11		

3.3.3.5 International players

All subjects were categorised as either:

1 - Involved with an international squad in the previous 12 months from the time of testing.

2 - No involvement with an international squad in the previous 12 months from the date of testing.

A subject who had previously been involved with an international squad but had no involvement during the twelve months prior to the date of testing was recorded as 2 (no involvement).

3.3.3.6 Playing position

The predominant playing position of each subject was recorded based on the positions outlined in the list on the following page.

Playing position codes

Goalkeeper – 1
Full-back – 2
Centre-back – 3
Midfield – 4
Forward – 5
Multi-positional – 6

In cases where no predominant playing position could be identified for a subject, the subject in question was subsequently recorded as being multi-positional (6).

3.3.3.7 Standing height

The standing height of each subject was measured using a Leicester Height Measure (SA). The procedure that was followed for all measurements of standing height is outlined.

Starting position

1. The subject removed all shoes and socks.
2. The subject was positioned with the heels, scapulae and buttocks touching the vertical part of the height measure. The subject was then verbally told to “relax as much as possible”.

Procedure

3. The subject’s head was then positioned in order that the lower borders of the orbits were in the same horizontal plane as the external auditory meati (The ‘Frankfurt’ Plane).
4. Gentle upward pressure was then exerted on the subject’s mastoid processes whilst encouraging the subject verbally to, “become as tall as possible”.
5. The measuring arm was then lowered gently onto the subject’s head.
6. The measurement was taken and recorded to the nearest complete millimetre when the maximum stature was achieved.

The subjects could not raise their heels from the ground (children very often do this). This difficulty was overcome by asking the subject verbally to "wiggle your toes" i.e. to raise the toes from the ground and move them. Whilst performing this action, the subject would have found it extremely difficult to raise the heels from the ground. The standing height measurements were taken at approximately the same time of day on each occasion, at the start of the academies evening training sessions 17:30-19:30 hours.

3.3.3.8 Body mass

The body mass of each subject was measured using SECA Analogue Floor Scale (SECA). The procedure that was followed for all measurements of body mass is outlined below.

Starting position/procedure

1. The subjects only wore very light clothing (underpants and or shorts).
2. The subject stood upright with both feet on the scales and was told verbally to "relax".
3. The measurement was taken when the scales 'settled' to the nearest 0.1kg.

To obtain the optimum accuracy the subjects were asked to evacuate their bowels and bladder prior to weighing, and the measurement was taken at approximately the same time of day on each occasion, at the start of the academies evening training sessions 17:30-19:30 hours.

3.3.3.9 Body Mass index; Reciprocal Ponderal Index and Somatotype

From the subjects' standing height and body mass measurements both body mass index (BMI; $kg.m^{-2}$) and reciprocal ponderal index (RPI; $cm.kg^{-0.333}$) were calculated. The subjects' RPI was then used to calculate their ectomorphic somatotype (Duquet and Carter, 1996).

3.3.3.10 Sexual maturation

The sexual maturation of each subject was assessed using a scale devised by Tanner (1962). A brief explanation of the method for assessing sexual maturity was given to the group of subjects to be tested. A detailed explanation of the method for assessing sexual maturity was then given to each individual in private, highlighting the confidential nature of the information being collected. Subjects then completed the following procedure in private, marking their choice on a card that was then placed in a sealed envelope that was only identifiable by the registration number. The results were completely private and were treated in complete confidence.

Tanner stages – male pubic hair development

1. Subjects were shown the pictures relating to the different stages of development of the male pubic hair (Appendix I).
2. Subjects looked at each of the pictures and read the sentences next to the picture (Appendix I).
3. Subjects then chose the picture closest to their stage of development and marked an A in the appropriate box on the form (Appendix J).
4. Subjects then chose the picture that was next closest to their stage of development and marked a B in the appropriate box on the form (Appendix J).

In choosing the right picture subjects were asked to look only at the pubic hair and not at the size of the testes, scrotum and penis.

3.3.4 Participants

A total of 2,252 elite child and adolescent soccer players (age 13.6±2.8 years; standing height 159.9±16.5 cm; body mass 51.6±16.2 kg) participated in this study unless otherwise indicated in the respective experimental chapters. The anthropometric characteristics of the subjects are summarized in Table 6.1.1. All the subjects were registered at one of twelve professional soccer club academies in England, and averaged between two to four training sessions and one match per week.

Estimated peak oxygen uptake ($\dot{V}O_{2peak}$) was measured in 727 subjects using the MSFT (Ramsbottom et al., 1988). A detailed description of the MSFT protocol can be found in section 3.4.5.

3.4 PHYSICAL PERFORMANCE TESTING PROTOCOL

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

<u>Pre-testing</u>

1. Club staff and players were informed as to the date, time and location of the testing.
2. All equipment was checked in terms of calibration and electrical charge.
3. All testing areas were accurately measured and marked (Appendix K).
4. All assistants/helpers for the testing were fully briefed with regards to their roles during the tests.

<u>During testing</u>

1. The principle and nature of the tests were introduced to the subjects i.e. what it is; what it measures.
2. The procedures and rules for the each test were explained to the subjects prior to each respective test.
3. Each testing procedure was demonstrated to the subjects.
4. The order of tests for each testing session was the same on each occasion and is outlined in the summary of the testing sequence below.
5. All physical performance testing scores were recorded on a data collection sheet (Appendix L).
6. Subjects were either tested in their age group squad or form class group in the soccer academies and schools, respectively.

Testing sequence summary

1. Standardised warm-up (to appropriate age group level), sub-maximal heart rate test and heart rate recovery test

3 minutes personal preparation

Jump test preparation (5 x squats; 5 x two foot ankle hops; 5 x two foot Counter Movement Jumps)

2. Jump tests (3 x Rocket Jump; 3 x Counter Movement Jump - without arms; 3 x Counter Movement Jump – with arms)

2 minutes personal preparation

2 x practice sprints (20 m)

3. Sprint test (2 x 10 m and 20 m)

2 x practice agility runs

4. Agility test (2 runs)
5. Multi-Stage Fitness Test (MSFT)*

*(Test 5, the MSFT was only administered in certain selected testing sessions)

All the physical performance tests were conducted at the indoor training facility of the respective soccer academies and schools involved in the research project. All physical performance tests were conducted on New Generation Synthetic Sports Turf. Subjects wore their normal soccer training shoe for all physical performance tests. Ad libitum fluid intake was permitted during the testing session after the measurement of body mass. A detailed description of the procedure for each physical performance test follows. All physical performance testing at the football academies was carried out during the evening training sessions (17:30 – 21:30 hours). The participants were measured and tested in their respective age-group squad over the course of the 2002-2003, 2003-2004 and 2004-2005 playing seasons.

The physical performance testing protocol was designed to allow age group squads (10 to 25 players) to be tested in a limited period of time (< 1 hour) so as not to impact too greatly on the coaches session time with their respective players. For example, the sprint and agility test layout (Figures 3.2 and 3.3) was designed to allow the players speed (10 m and 20 m) and then agility to be tested without having to move the start and finish timing gates between the speed and agility tests.

3.4.1 Standardised warm-up, sub-maximal heart rate test and heart rate recovery test

1. The MSFT compact disc was calibrated before each testing session in accordance with procedures outlined by sports coach UK (2002).
2. Heart rate straps (Polar Team System®) were given to the top 10 subjects from an alphabetical squad/class list. The straps were set up to record the heart rate average at 5 s intervals using short wave telemetry.
3. Subjects performed the MSFT (Ramsbottom et al., 1988) up to a pre-determined level dependent on their age group classification (See Table 3.1).
4. When the pre-determined level was reached the subjects walked along the 20 m shuttle at their own pace for 2 min.
5. Heart rate straps were then removed from subjects.
6. The information on the heart rate straps was downloaded following the testing session by interfacing the straps with a microcomputer.
7. The average heart rate for each level of the MSFT was determined and recorded for the sub-maximal heart rate test.
8. The maximal heart rate and the recovery heart rate at 60 and 120 seconds after reaching the specified level was recorded for the heart rate recovery test.
9. Subjects were then given 3 min of their own personal preparation time prior to the start of the jump tests.

On a selected session during the physical performance testing programme subjects ran to maximum on the multi-stage fitness test (Ramsbottom et al., 1988). The level that subjects reached on the maximum test was recorded

(Appendix M), and a $\dot{V}O_{2peak}$ value was estimated using the tables described by Ramsbottom and colleagues, (1988) (Appendix N). Subjects walked for two minutes at their own pace having reached their maximum level. For those subjects who were allocated heart rate straps, maximum heart rate was recorded (beats.min^{-1}) along with the heart rate at 60 and 120 s post maximum heart rate. When subjects ran to maximum on the multi-stage fitness test the order of tests was slightly altered. The order of tests remained the same, except for the multi-stage fitness test being conducted after the agility tests and a standardised warm up consisting of jogging, dynamic flexibility and striding being performed for 15 min in place of the sub-maximal multi-stage fitness test at the start of the testing session (See Testing Sequence Summary).

Table 3.1. Level of the multi-stage fitness test which the test was stopped for each age group classification.

Age Group	Level
Under 9's	End of Level 4
Under 10's	End of Level 5
Under 11's	End of Level 5
Under 12's	End of Level 6
Under 13's	End of Level 6
Under 14's	End of Level 7
Under 15's	End of Level 7
Under 16's	End of Level 8
Under 17's	End of Level 8
Under 18's	End of Level 8
Under 19's	End of Level 8

3.4.2 Jump tests

As part of the preparation for the jump tests all subjects performed five squats, five two foot ankle hops and five two foot counter movement jumps. All subjects were then instructed to stay in a 10 x 10 m preparation grid before being called in alphabetical order to the jump mat (Appendix K). The height of all jumps was recorded using a Newtest Powertimer Jumpmat (Newtest Oy®). This system uses flight time to calculate the height of rise of the subject's centre of gravity, based on the following equation:

$$h = g \times t2 / 8$$

Where:

h = height of rise of the centre of gravity (m)

g = acceleration of gravity ($9.81ms^{-2}$)

t = flight time (s)

i. Rocket jump (RJ)

1. Subjects were called in alphabetical order from the preparation grid.
2. The subjects were then instructed to stand with their feet shoulder width apart on the jump mat in the chalked landing zone (See Figure 3.1).
3. The subjects were then instructed to place both hands on their hips and squat down to their lowest comfortable position.
4. From this position the subjects jumped vertically as high as possible.

The subjects' hands had to remain on their hips throughout the jump. No initial downward movement was permitted immediately prior to the upward movement of the jump. The subject had to take off and then land with straight legs in the chalked landing zone. If any of these points were violated the jump was deemed invalid and was then repeated.

5. Each subject performed three valid jumps and then returned to the preparation grid.
6. The height (cm) of the subjects' three jumps were recorded on the data collection sheet (Appendix L).
7. The height (cm) of each subject's highest jump was then used for the purpose of data analysis.

ii. Counter movement jump – without arms (CMJ)

1. Subjects were called in alphabetical order from the preparation grid.

2. The subjects were instructed to stand with their feet shoulder width apart on the jump mat in the chalk landing zone with both hands on their hips (See Figure 3.1).
3. From this standing position the subjects performed a counter movement jump.

The subjects' hands had to remain on their hips throughout the jump. The subjects had to take off and land then land with straight legs in the chalk landing zone. If any of these points were violated the jump was deemed invalid and was then repeated.

4. Each subject performed three valid jumps and then returned to the preparation grid.
5. The heights (cm) of the subjects' jumps were recorded on the data collection sheet (Appendix L).
8. The height (cm) of each subject's highest jump was then used for the purpose of data analysis.

<u>iii. Counter movement jump – with arms (CMJA)</u>

1. Subjects were called in alphabetical order from the preparation grid.
2. The subjects were instructed to stand with feet shoulder width apart on the jump mat in the chalk landing zone (See Figure 3.1).
3. From this standing position the subjects performed a counter movement jump using their arms to assist them during the jump.

The subjects had to take off and then land with straight legs in the chalk landing zone. If this point was violated the jump was deemed invalid and was then repeated.

4. Each subject performed three valid jumps and then returned to the preparation grid.
5. The heights (cm) of the subjects' jumps were recorded on the data collection sheet (Appendix L).
6. The height (cm) of each subject's highest jump was then used for the purpose of data analysis.
7. The subjects were then given 2 minutes of their own personal preparation time prior to the start of the sprint tests.

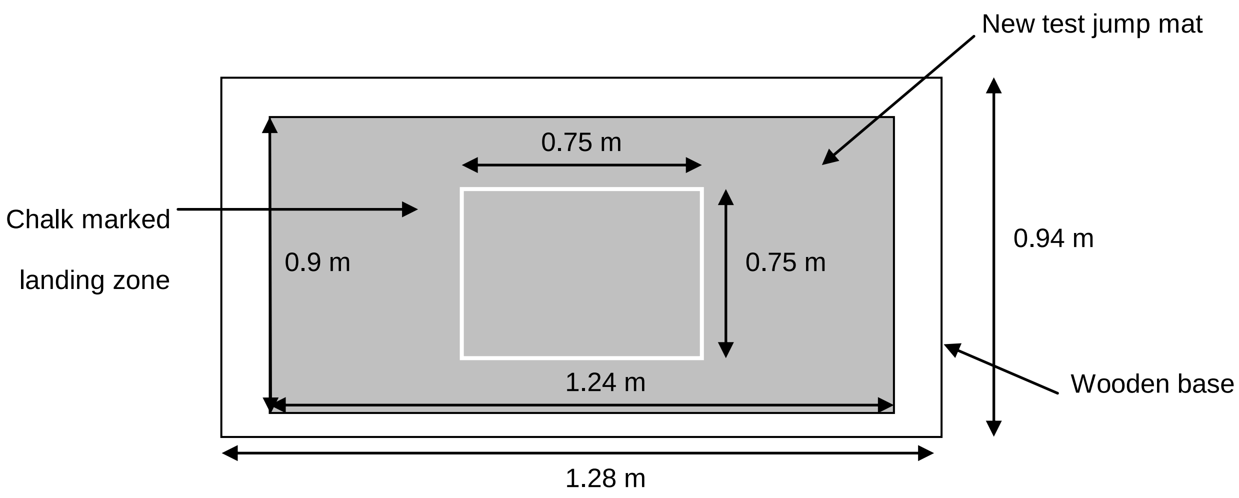


Figure 3.1. Jump Test Layout.

3.4.3 Sprint tests

The times for both the sprint and agility tests were recorded using photoelectric timing gates (Newtest Oy®). All testing was conducted with the photoelectric timing gates set up at 85 cm in terms of height from the ground surface.

1. Each subject was given 2 practice runs through the sprint course (Figure 3.2).
2. All subjects were then instructed to stay in a 10 x 10 m preparation grid before being called to the starting line (Appendix K).
3. Subjects were called in alphabetical order from the preparation grid.
4. The subjects were instructed to stand with their preferred foot on the start line, 1 metre behind the start timing gate (Figure 3.2).
5. The subjects then started the sprint when they were ready, accelerating through the start timing gate, 10 m timing gate, 20 m timing gate and the finishing gate (Figure 3.2).
6. The time taken to cover 10 m and 20 m was recorded to the nearest 1000th of a second on the data collection sheet (Appendix L).
7. The subjects fastest time recorded over 10 m and 20 m (to the nearest 1000th of a second), respectively, was used for the purpose of data analysis.

8. The subjects then returned to the preparation grid before being called back for their second timed sprint.

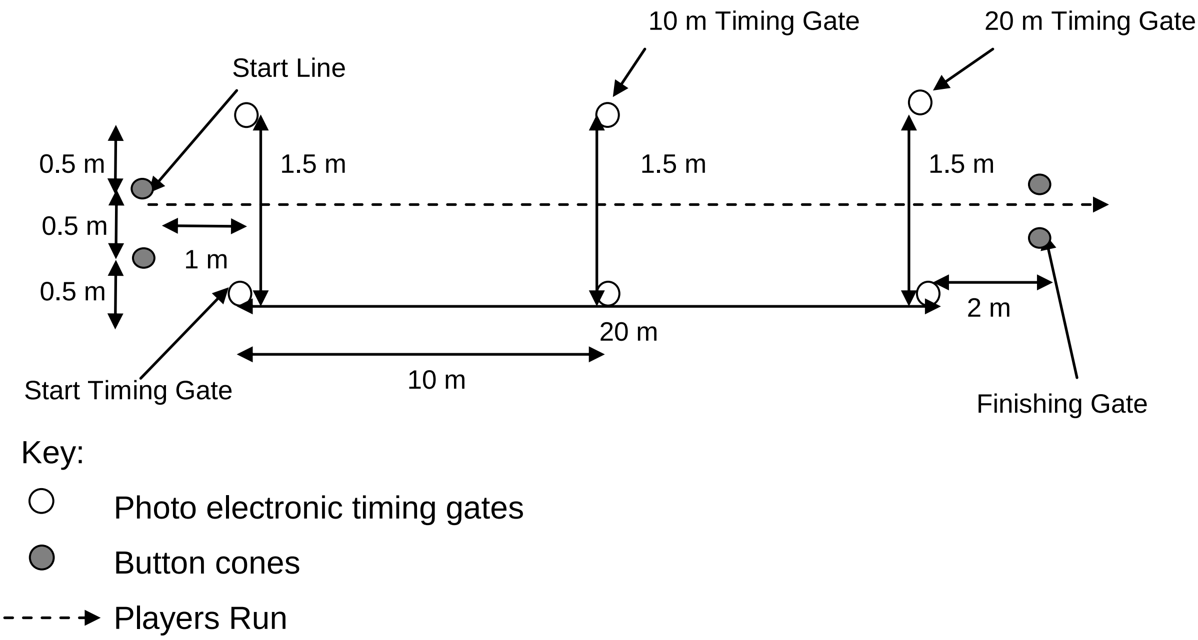


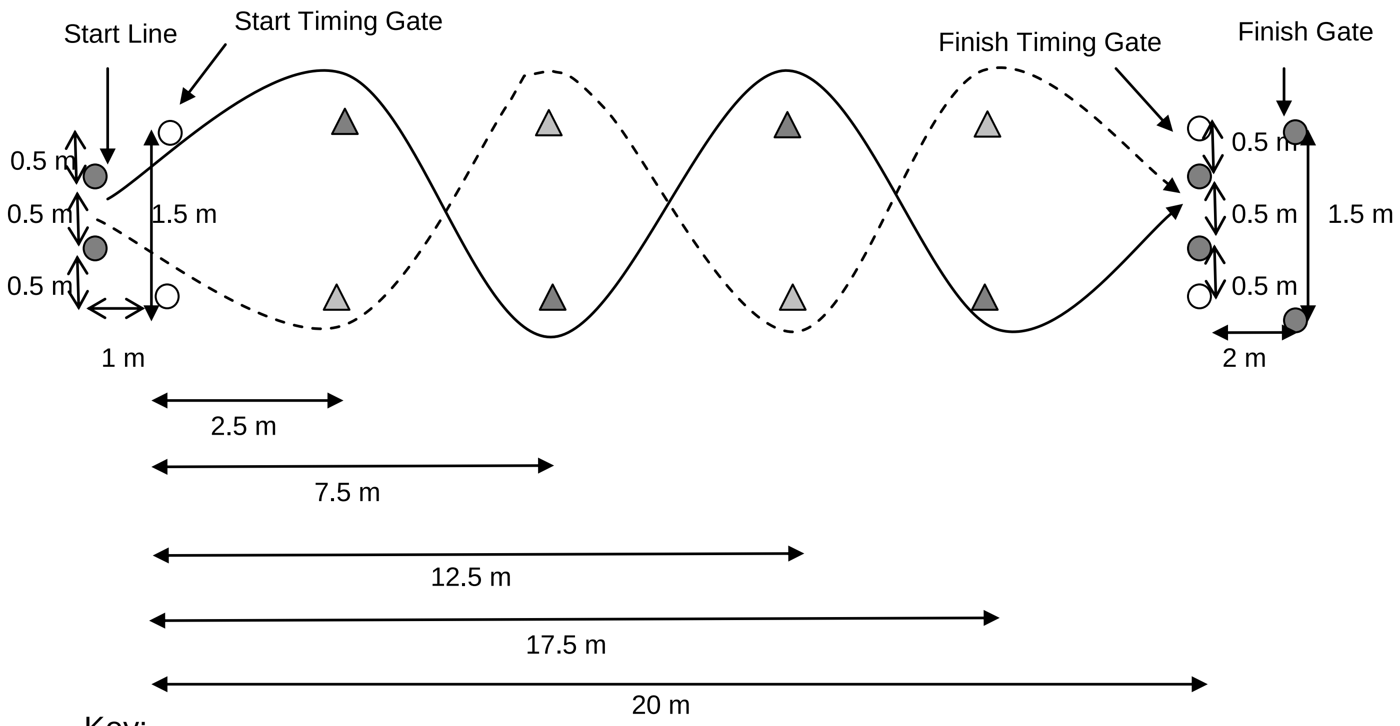
Figure 3.2. Sprint Test Layout.

3.4.4 Agility test

1. Each subject was given 2 practice runs through the course, one run on each course (Figure 3.3).
2. All subjects were instructed to stay in a 10 x 10 m preparation grid before being called to the starting line.
3. Subjects were called in alphabetical order from the preparation grid.
4. The subject was instructed to stand with their preferred foot on the start line, 1 m behind the start timing gate (Figure 3.3).
5. The subject then started run 1 in their own time accelerating through the start timing gate and around the outside of the 4 green cones and through the finish timing gate and finishing gate (Figure 3.3).
6. The time taken to complete run 1 was recorded to the nearest 1000th of a second on the data collection sheet (Appendix L).
7. The subject then returned to the preparation grid before being called back for run 2 around the red cones (Figure 3.3).

8. The subjects' average time (to the nearest 1000th of a second) for the two agility runs was used for the purpose of data analysis.

Subjects were not permitted to touch any cones during the course of the agility test. If a cone was touched during the test, the run was deemed invalid and was then repeated.



Key:

- Button Cones
- Light Cells
- Large Cones (Height 45 cm)
- Players Run 1 / Players Run 2

Figure 3.3. Agility Test Layout.

3.4.5 MSFT

At the end of certain selected testing sessions subjects performed the MSFT (Ramsbottom et al., 1988).

1. Prior to the MSFT subjects were informed to give their maximum effort and attempt to reach the highest level possible before stopping.

2. In some cases the subjects withdrew voluntarily from the test. However, in other cases individual subjects were withdrawn from the test if they were no longer complying with test regulations. In line with the recommendations of Brewer, Ramsbottom and Williams (2002) subjects were given two verbal warnings if they failed to reach the line before the audio signal and were then withdrawn from the test after a third failure.
3. The level and the number of shuttles into the level at which each subject withdrew from the test was recorded (Appendix M).
4. An estimate of peak oxygen uptake ($\dot{V}O_{2peak}$) was then obtained from a table of predicted $\dot{V}O_{2max}$ values derived from young adult data (Ramsbottom, Brewer and Williams, 1988).

3.5 STATISTICAL ANALYSIS

Data were analysed using SPSS (Version 16.0, Chicago, Illinois, USA) and MLwiN (Version 2.16, Bristol, U.K.). Descriptive statistics were calculated.

The validity and reliability of the physical performance tests (Chapter 5) was determined using a number of statistical techniques including, intraclass correlation (ICC), Bland and Altman limits of agreement (Bland and Altman, 1986), typical error (Hopkins, 2000), repeatability (Bland and Altman, 1996), within-subject coefficient of variation, two way analysis of variance (ANOVA) and paired *t*-tests.

Independent *t*-tests were used to investigate differences in anthropometric and physical performance variables between sexual maturity groups (Chapter 7.2), professional status (professional graduates vs. non-professional graduates) and professional playing status (professional appearance vs. no professional appearance) (Chapter 9.4).

One-way analysis of variance (ANOVA) was used to investigate differences in anthropometric and physical performance variables between age groups (Chapter 6.1), playing positions (Chapter 6.2), ethnic groups (Chapter 6.3), birth quartiles (Chapter 7.1), sexual maturity groups (Chapter 7.2) and professional playing levels (Chapter 9.4). When a significant age group, playing position, ethnic group, birth quartile, sexual maturity group or professional playing level effect was found a Tukey post hoc test was used to test differences among means.

Two-way analysis of variance (ANOVA) was used to investigate differences in anthropometric and physical performance variables between the different playing ability groups, age groups and the interaction between playing ability group and age (Chapter 9.1). When a significant interaction playing ability group*age was found post hoc pairwise bonferroni analysis by age group was conducted (Chapter 9.1). Two-way analysis of variance (ANOVA) was also used to investigate differences between released and retained academy players (Chapter 9.2) and different playing ability groups of academy players (Chapter 9.3)

Pearson correlation coefficients (r) were calculated to determine the statistically significant relationships ($p<0.01$) between the different measurements of physical performance (Chapter 6.1).

A chi-square test was used to test the observed and expected playing position distribution within the ethnic groups (Chapter 6.3). A chi-square test was also used to test the observed and expected birth distribution across the sample of academy players involved in the study (Chapter 7.1).

In Chapter 6.1, 6.2 and 7.1 standing height and body mass measurements were compared against British 1990 growth reference centiles (Cole et al., 1998) using the LMS method (Cole and Green, 1992).

Binomial logistic regression was used to compare the anthropometric and physical performance characteristics of non-players vs. school players and school pupils vs. academy players (Chapter 9.1). Multilevel modelling was used to analyse the longitudinal development of anthropometric and physical performance characteristics of elite young players (Chapter 8) and to compare the anthropometric and physical performance characteristics of professional graduates vs. non-professional graduates (Chapter 9.4). This form of analysis is an extension of multiple regression, and is used when data are hierarchically structured. For the present data repeated measurements were regarded as 'nested' within players, who were regarded as nested within soccer clubs. Consequently, the hierarchal structure used for the analysis described in Chapter 9.4 had repeated measurements at level 1, player at level 2, and soccer club at level 3 of the multilevel models.

Statistical significance was accepted at the 95% confidence level ($p<0.05$). Values are reported as mean ($\pm$SD).

CHAPTER 4
PHYSICAL PERFORMANCE IN SOCCER

4.1 INTRODUCTION

Soccer has been described as a multifaceted sport, comprising several technical, tactical and physical factors (Stolen et al., 2005). Within this context coaches, players and support staff all harbour beliefs on the factors that determine success at the elite level of soccer. The present chapter will only reflect on opinions relating to the physical aspect of soccer performance.

Much of what is conveyed in relation to the elite game through the media, either on television or in newspapers and books is based on little more than the subjective observations of those who are involved. For example, commentators may often refer to the physical attributes of individual players, using descriptions such as ‘strong’, ‘agile’, ‘powerful’ or ‘quick’. Such observations often constitute the basis on which the physical strengths and weaknesses of a player are assessed. Observations of this nature may have a profound effect on the individual in question, including, their playing position and ultimately the playing level which they attain.

Coaches are continually making subjective observations on the physical characteristics of individual players. Clearly these observations are based on their interpretation of players’ physical performances. This interpretation of physical performance will be based on their understanding and beliefs relating to the physical aspects of performance in soccer. For example, some coaches may regard speed to be the most important physical attribute in a player, whilst others may consider endurance to be paramount to performance. Although such discussions often take place within the soccer environment between coaches, support staff and players a general consensus of opinions has yet to be documented. Detailing these opinions would provide an insight of how physical performance in soccer is perceived, the level of importance that is placed on various physical attributes and how physical factors may effect decisions that are made in relation to players, for example in terms of the selection process and when assessing a players suitability for different positions.

Bangsbo (1994) made the observation that soccer is not a science, but that science may help improve performance. In relation to this it is important to gain an appreciation of how sports science, in particular physical performance testing is perceived by coaches, support staff and players. For example, what importance do coaches place on physical performance test results and do the results have any impact on subsequent decisions that are made in relation to players in terms of selection. An insight into the perception of physical performance testing within the soccer environment may give direction to the process by which such testing is administered and how the subsequent information is best utilised.

The purpose of this study was to examine the understanding and beliefs of coaches, fitness professionals and players in relation to the physical aspects of performance in soccer. Particular attention was given to how physical performance testing was perceived and utilised within the elite soccer setting. The hypothesis to be tested was that coaches, fitness professionals and players perceive the physical aspects of performance in soccer to be very important in the context of the elite player

4.2. METHODS

4.2.1 Questionnaire design, administration and analysis

The design, administration and analysis of the questionnaires relating to physical performance and testing in soccer is outlined in the general methods (Chapter 3). The questionnaires administered to coaches, fitness professionals and players are detailed in appendices N, O and P, respectively.

4.2.2 Participants

Four hundred and forty three questionnaires were completed by coaches (n=170), fitness professionals (sports scientists; strength and conditioning coaches; physiotherapists, etc.) (n=172) and players (n=101), respectively (Table 4.1).

Table 4.1. Questionnaire participant information.

Age (years)	Coach		Fitness Professional		Player		
	Male	Female	Male	Female	Age Group	Male	Female
	169	1	126	46		101	0
0-20	5		78		U14	13	
21-30	43		51		U15	17	
31-40	57		34		U16	27	
41-50	51		8		U17	19	
51-60	13		1		U18	8	
61-70	1		0		U19	17	
71+	0		0		Senior	0	

4.3 RESULTS

4.3.1 Physical performance in soccer

For the majority of coaches and players the attributes of an elite player in order of importance were technical, physical/physiological, psychological and social (Table 4.2). Slightly more fitness professionals (45.3 vs. 43.0%) viewed physical/physiological attributes to be more important than technical attributes (Table 4.2).

Table 4.2. Coach, fitness professional and player opinions on the attributes of the elite player in order of importance.

Attribute	Order of Importance	Coach (%)	Fitness Professional (%)	Player (%)
Physical/Physiological	1st	29.4	45.3	26.7
	2nd	57.1	44.8	36.6
	3rd	11.8	8.7	29.7
	4th	1.8	1.2	6.9
Technical	1st	62.9	43.0	55.4
	2nd	28.8	38.4	30.7
	3rd	7.6	15.7	10.9
	4th	0.6	2.9	3.0
Psychological	1st	5.9	10.5	14.9
	2nd	12.9	16.3	29.7
	3rd	75.3	71.5	45.5
	4th	5.9	1.7	9.9
Social	1st	1.8	1.2	3.0
	2nd	1.2	0.6	4.0
	3rd	5.3	4.1	12.9
	4th	91.8	94.2	80.2

Coaches considered speed to be the most foremost physical attribute in elite players, with 80.5% of the respondents assessing it to be ‘very important’ (Figure 4.1). This contrasted with the players opinions, with only 26.5% believing speed to be a ‘very important’ attribute in elite players (Figure 4.1). Both the players and fitness professionals regarded endurance as the principal physical attribute, with 55.4% and 65.8% regarding it as ‘very important’, respectively (Figure 4.1). The perceived importance of balance/co-ordination and agility in elite players was also highlighted by the opinions of coaches, fitness professionals and players (Figure 4.1).

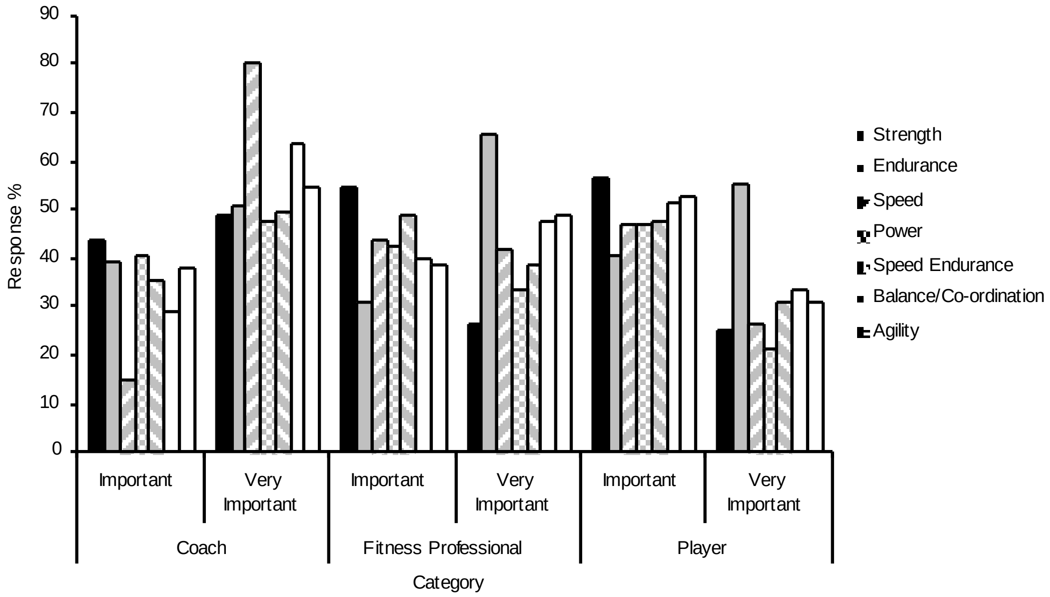


Figure 4.1. The importance placed on different physical attributes in elite players by coaches, fitness professionals and players.

The majority of coaches (88.8%), fitness professionals (93.0%) and players (89.1%) believed that the relative importance of the various physical components differed between different playing positions. Agility and balance/co-ordination were considered to be the most important physical attributes for a goalkeeper, with little importance being placed on endurance and speed endurance (Table 4.3). Coaches identified speed and speed endurance as the key physical attributes for a fullback, whilst the players put more importance on endurance (Table 4.3). In relation to centrebacks, strength and power were regarded as the principle physical attributes with endurance and speed endurance being viewed as less important (Table 4.3). Endurance was perceived as the most significant physical attribute for a midfield player to possess (Table 4.3). In terms of forward players, speed was identified as the key attribute, with 90.8% of the coaches considering it to be ‘very important’ (Table 4.3).

The physical attributes of a player were regarded as having a crucial role to play in the process of offering professional playing contracts (Table 4.4). Coaches, as opposed to fitness professionals and players, appeared to place more importance on physical attributes when considering the process of offering professional playing contracts (Table 4.4).

Table 4.3. The importance placed on various physical attributes for different playing positions in soccer by coaches, fitness professionals and players.

Playing Position	Physical Attribute	Coach (%)		Fitness Professional (%)		Player (%)	
		Important	Very Important	Important	Very Important	Important	Very Important
Goalkeeper	Strength	39.4	50.8	41.1	32.9	28.9	28.9
	Endurance	17.4	4.5	11.6	0.7	9.2	9.2
	Speed	36.6	33.6	35.6	29.5	25.0	17.1
	Power	33.6	55.7	32.9	37.7	35.5	36.8
	Speed Endurance	15.3	3.8	15.8	5.5	13.2	5.3
	Balance/Co-ordination	9.9	87.0	9.6	87.7	18.4	77.6
	Agility	5.3	92.4	8.9	86.3	17.1	77.6
Fullback	Strength	57.3	30.5	40.4	39.0	50.0	32.9
	Endurance	43.5	50.4	38.4	48.6	34.2	60.5
	Speed	24.4	70.2	41.1	48.6	43.4	42.1
	Power	49.6	32.8	50.0	32.9	44.7	25.0
	Speed Endurance	31.3	60.3	37.0	45.2	39.5	43.4
	Balance/Co-ordination	42.7	43.5	50.7	30.1	50.0	30.3
	Agility	42.7	39.7	44.5	37.0	46.1	30.3
Centreback	Strength	10.7	87.0	21.2	69.2	15.8	84.2
	Endurance	56.5	26.7	52.1	27.4	50.0	28.9
	Speed	38.2	55.0	54.1	29.5	47.4	34.2
	Power	23.7	74.0	35.6	50.0	34.2	63.2
	Speed Endurance	51.9	26.7	49.3	22.6	52.6	18.4
	Balance/Co-ordination	53.4	39.7	45.2	32.2	38.2	38.2
	Agility	48.1	37.4	45.2	32.2	42.1	32.1
Midfielder	Strength	45.8	45.8	45.2	39.0	59.2	28.9
	Endurance	8.4	88.5	13.0	83.6	13.2	82.9
	Speed	46.6	48.1	41.1	47.9	48.7	32.9
	Power	45.0	41.2	43.8	42.5	50.0	25.0
	Speed Endurance	24.4	71.0	32.2	60.3	42.1	48.7
	Balance/Co-ordination	42.0	53.4	48.6	39.7	44.7	36.8
	Agility	39.7	50.4	36.3	52.7	40.8	43.4
Forward	Strength	31.3	65.6	43.8	43.2	38.2	55.3
	Endurance	56.5	29.8	41.1	39.0	36.8	35.5
	Speed	7.6	90.8	12.3	84.9	26.3	69.7
	Power	28.2	67.9	37.0	57.5	38.2	55.3
	Speed Endurance	35.9	54.2	32.2	58.2	44.7	46.1
	Balance/Co-ordination	33.6	62.6	30.1	63.0	46.1	46.1
	Agility	26.7	65.6	30.8	61.0	42.1	48.7

Table 4.4. The perceived importance of a player's physical attributes in the process of offering professional playing contracts.

Importance	Coach (%)	Fitness Professional (%)	Player (%)
Don't Know	1.8	6.5	5.0
Not at all important	1.2	2.4	1.0
Not really important	2.4	3.5	3.0
Slightly important	8.8	10.0	14.9
Important	44.1	40.0	41.6
Very Important	41.8	37.6	34.7

The majority of coaches (71.2%), fitness professionals (68.6%) and players (65.3%) considered the physical attributes of international players to be different to those of club players. Many of those respondents who believed differences to exist between international and club players in terms of physical attributes suggested that international players displayed superior physical characteristics in comparison to club players (Figure 4.2). In particular it was perceived that international players were faster, more agile and possessed better balance/co-ordination (Figure 4.2).

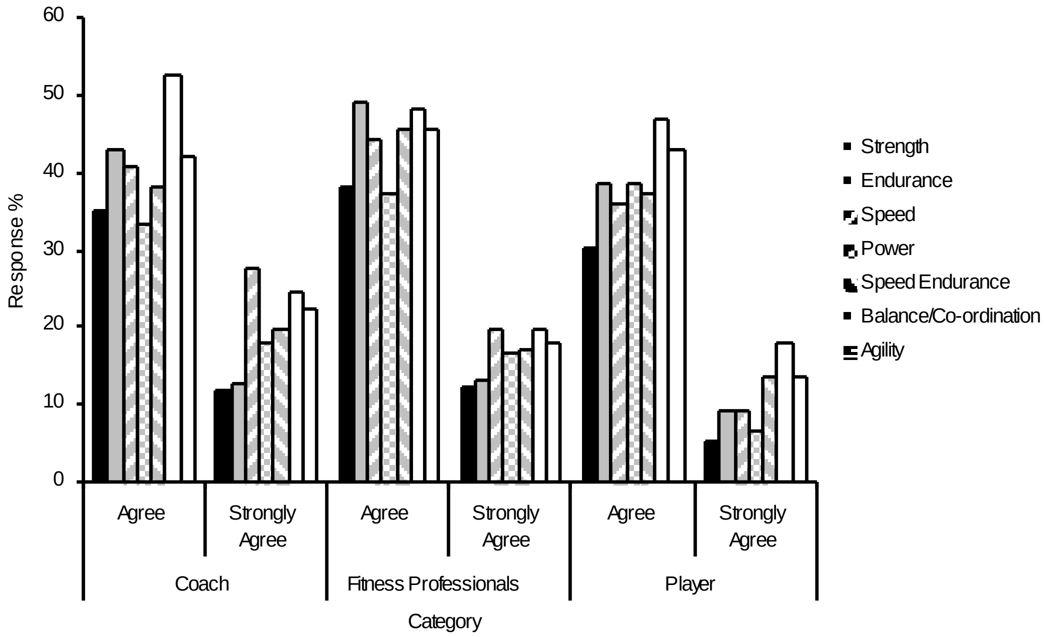


Figure 4.2. Physical attributes that are perceived to be superior in international players in comparison to club players.

Most coaches (93.5%), fitness professionals (86.6%) and players (83.2%) were of the opinion that the physical/physiological attributes of players are more important in terms of the modern day game. These same respondents suggested that modern players had advanced in terms of a number of physical characteristics over the last 30 years (Figure 4.3). Speed was seen as one of the main physical characteristics to have improved in relation to the modern player (Figure 4.3).

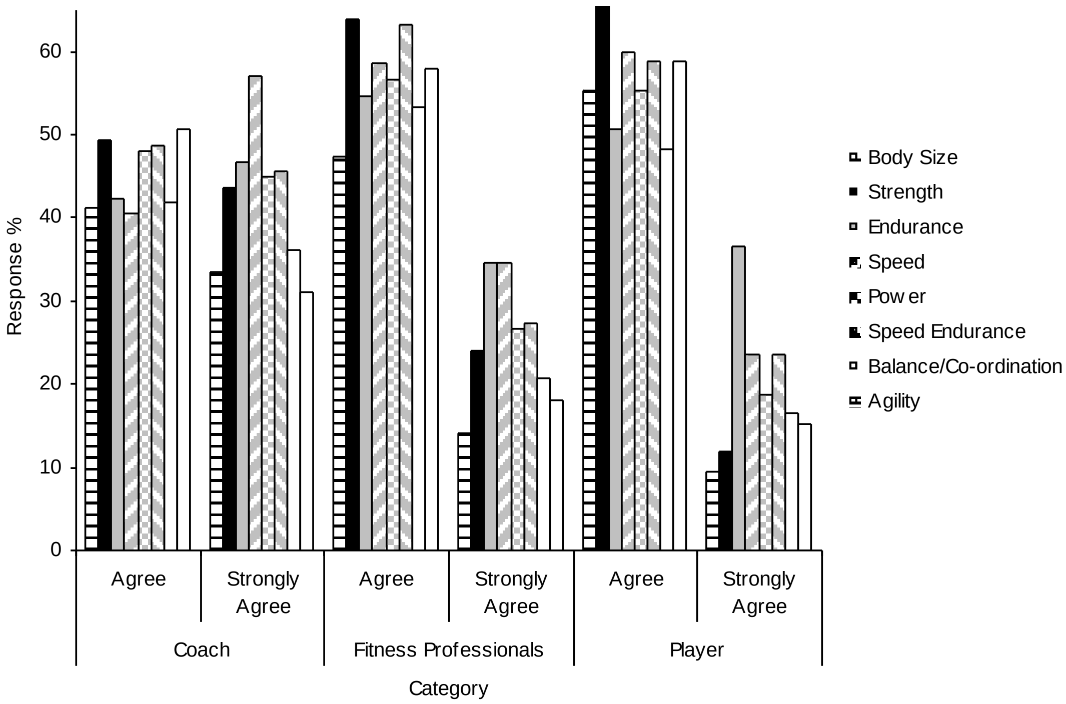


Figure 4.3. Physical attributes that are understood to have advanced in relation to the modern player over the last 30 years.

A widely held belief amongst coaches (73.5%), fitness professionals (52.9%) and players (74.3%) was that players from certain ethnic backgrounds were naturally more physically able in comparison to other players. In particular this belief was associated with Black African and Black Caribbean players (Figure 4.4). The perception of being more physically able was particularly related to the attributes of speed, power and strength (Figure 4.4).

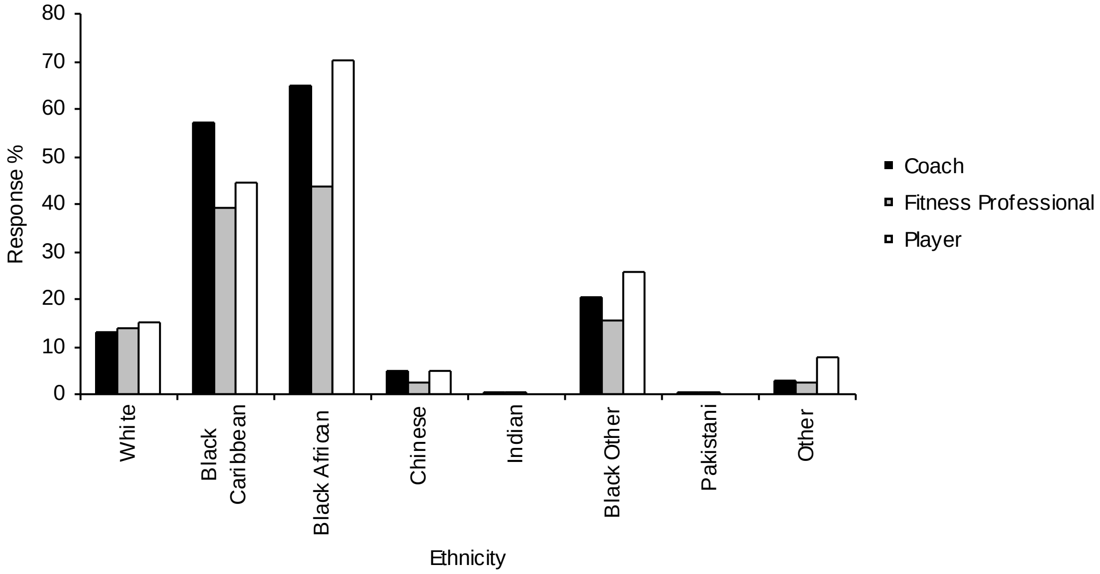


Figure 4.4. Ethnic groups that are considered to be naturally physically advantaged for the purpose of soccer performance.

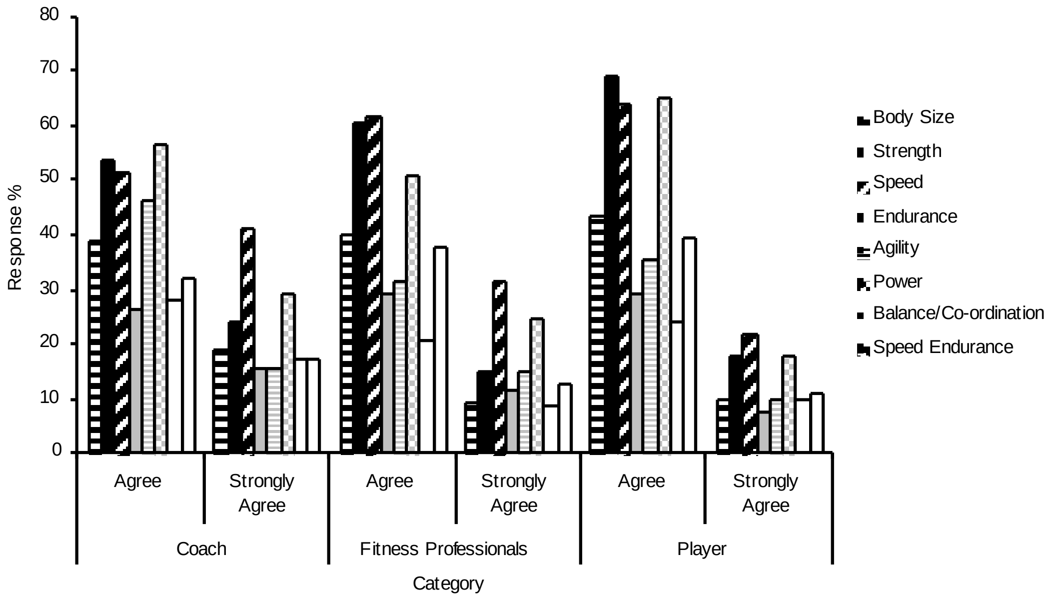


Figure 4.5. Physical attributes in which certain ethnic groups are perceived to be naturally advantaged for the purpose of soccer performance.

4.3.2 Physical performance testing in soccer

Most coaches (97.0%), fitness professionals (93.5%) and players (83.1%) thought that physical performance testing was an important aspect of preparation in soccer. It was deemed important to test a number of different physical attributes, although more coaches thought speed was 'very important' to test (Figure 4.6).

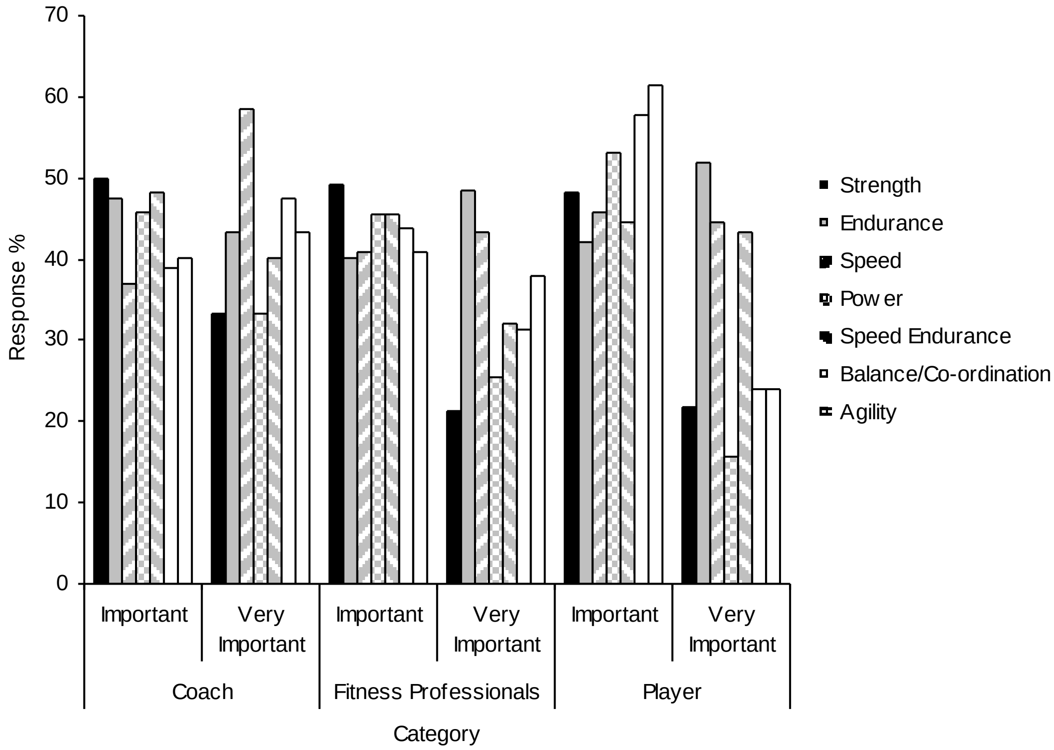


Figure 4.6. The importance placed on performance testing various physical attributes by coaches, fitness professionals and players.

Some coaches (40.2%), fitness professionals (47.3%) and players (56.6%) thought it possible to make accurate assessments of players physical attributes from observing a game. Those who considered that accurate physical evaluations could be made from game observations suggested that speed and endurance were two attributes which were more assessable during a game (Figure 4.7). However, most coaches (75.0%), fitness professionals (65.7%) and players (60.2%) considered that objective measurements from physical performance tests offered a more accurate assessment of physical performance than subjective observations taken from a game.

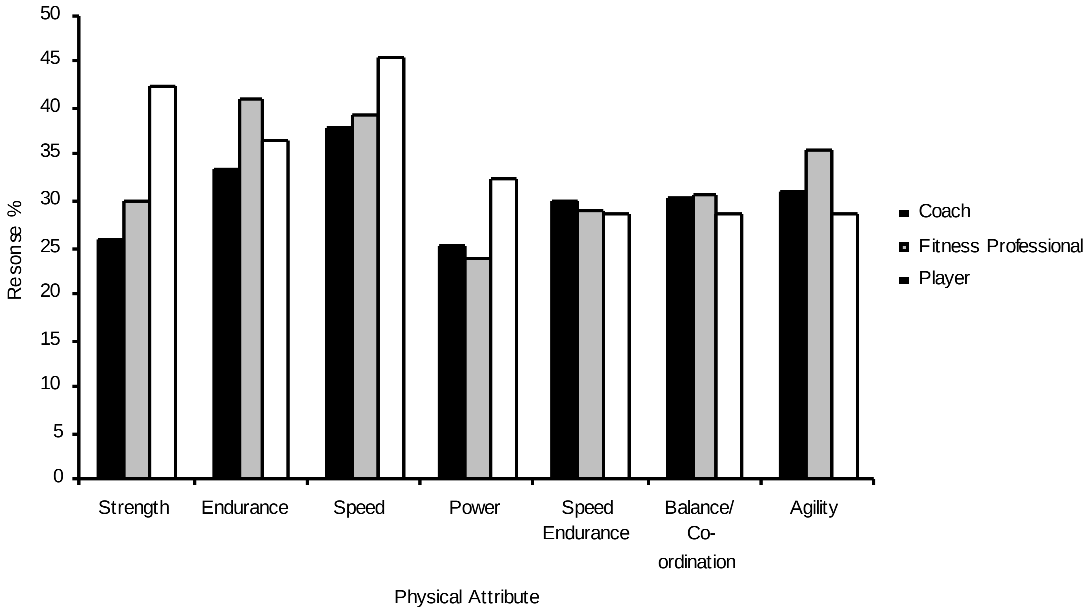


Figure 4.7. Physical attributes which coaches, fitness professionals and players deemed could be accurately assessed whilst observing a game.

The information provided by objective physical performance testing was considered to have an important bearing on a number of processes within the soccer environment, for example talent identification and monitoring progress and development (Figure 4.8). Coaches perceived physical performance testing to be of prime importance in the process of monitoring the progress and development of players (Figure 4.8).

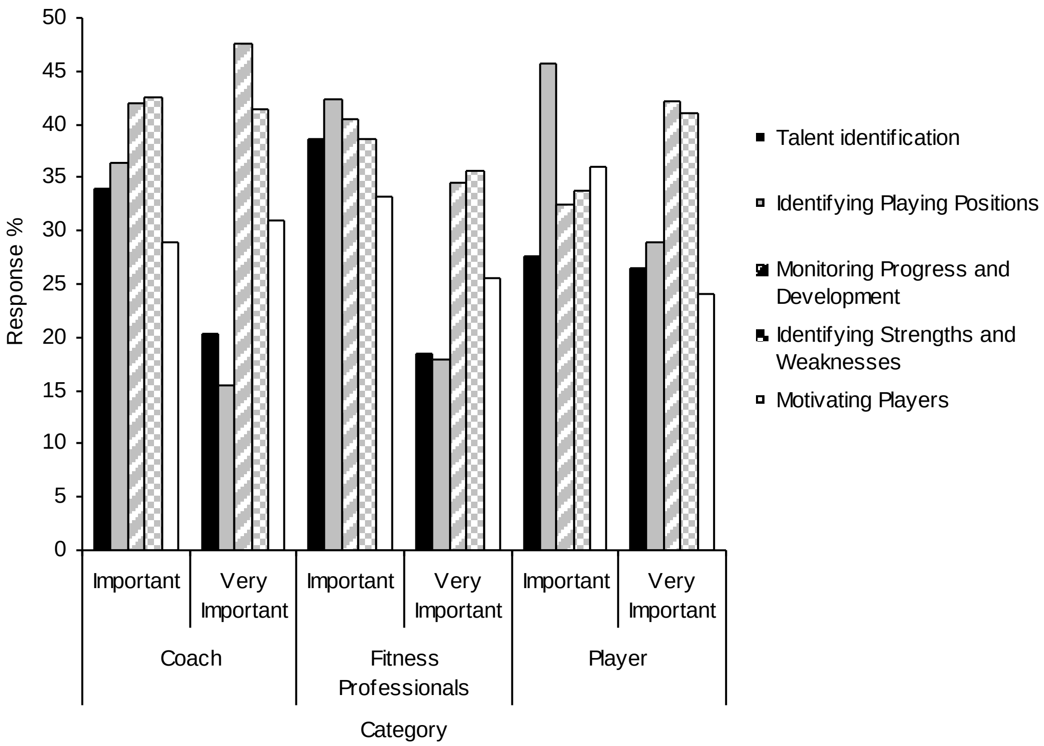


Figure 4.8. Areas for which coaches, fitness professionals and players believed physical performance testing provided important information.

The majority of coaches (79.5%), fitness professionals (78.6%) and players (72.3%) believed that both laboratory and field-based physical performance tests were valuable tools to use in the soccer environment (Figure 4.9). However, it was evident that field-based tests were thought to be of slightly more value than laboratory based assessments (Figure 4.9).

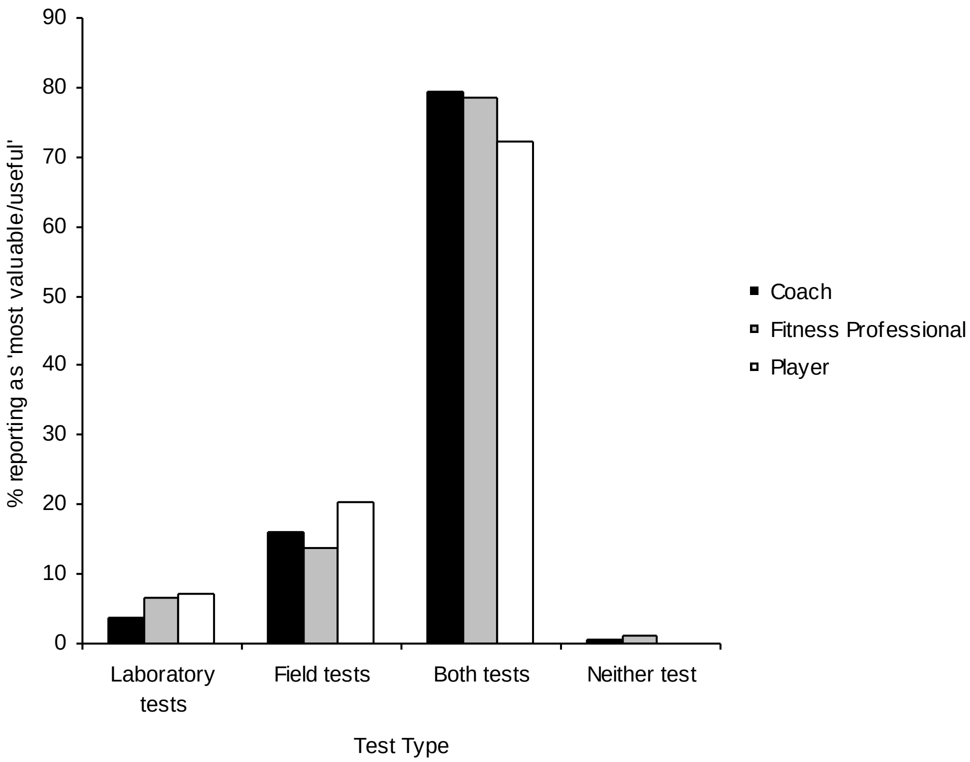


Figure 4.9. The value which coaches, fitness professionals and players placed on laboratory and field-based physical performance tests in the soccer environment.

Coaches, fitness professionals and players suggested that there were some problems associated with physical performance testing in soccer, for example lack of time to implement tests and the associated cost of testing (Table 4.5). Coaches suggested that the main problem with physical performance testing in soccer was a lack of facilities/equipment to conduct testing sessions (Table 4.5).

Table 4.5. Problems that coaches, fitness professionals and players associated with physical performance testing in soccer.

		Lack of time (%)	Lack of facilities/equipment (%)	Lack of expertise (%)	Player compliance (%)	Relevance of results (%)	Cost (%)
Coach	Don't Know	3.1	2.5	3.1	4.3	5.6	6.2
	Strongly disagree	1.9	1.9	3.1	7.5	8.7	1.9
	Disagree	5.6	7.5	7.5	31.1	25.5	12.4
	Neither agree/disagree	6.8	7.5	11.8	25.5	26.1	14.3
	Agree	61.5	52.8	49.1	29.2	31.1	41.0
	Strongly agree	21.1	28.0	25.5	2.5	3.1	24.2
Fitness Professional	Don't Know	9.5	7.1	7.7	10.7	9.5	10.7
	Strongly disagree	2.4	0.6	0.6	4.2	7.1	0.6
	Disagree	18.5	10.7	16.7	18.5	26.2	8.9
	Neither agree/disagree	21.4	14.3	23.8	21.4	23.2	20.2
	Agree	43.5	55.4	43.5	37.5	28.6	45.2
	Strongly agree	4.8	11.9	7.7	7.7	5.4	14.3
Player	Don't Know	14.5	7.2	9.6	9.6	12.0	13.3
	Strongly disagree	6.0	6.0	7.2	4.8	7.2	4.8
	Disagree	22.9	27.7	25.3	14.5	21.7	20.5
	Neither agree/disagree	22.9	20.5	19.3	24.1	26.5	27.7
	Agree	30.1	31.3	34.9	42.2	26.5	28.9
	Strongly agree	3.6	7.2	3.6	4.8	6.0	4.8

4.4 DISCUSSION

The results of the present study suggest that coaches and players perceive technical attributes to be of primary importance when considering the elite player (Table 4.2). Physical/physiological attributes were considered to be of secondary importance, above psychological and social attributes respectively. This finding may explain why some have argued that efforts to improve soccer performance often focus on technique and tactics at the expense of physical fitness (Stolen et al., 2005). However, the recent increase in the number of studies relating to soccer specific physical training (Helgerud et al., 2001 ; Hoff and Helgerud, 2004; McMillan et al., 2005) would support the current finding that physical/physiological attributes are regarded as being important in the make up of an elite player. Slightly more fitness professionals believed physical/physiological attributes to be more important than technical attributes which further underlines the significance placed on the physical/physiological characteristics of elite players. Furthermore, most coaches, fitness professionals and players thought that the physical attributes of a player were regarded as being important in relation to the process of offering professional playing contracts (Table 4.4).

It is understood that the physiological demands of soccer require players to be competent in a number of aspects of physical fitness, including endurance, power, flexibility, strength and agility (Svensson and Drust, 2005). In relation to this our results illustrate that most coaches deemed speed to be the most important physical attribute of an elite player (Figure 4.1). Speed is often referred to in the literature as an important component in soccer, the ability to accelerate often deciding important outcomes in a game (Stolen et al., 2005). Indeed players have to accelerate quickly over short distances to meet the technical, tactical and physical demands of the game (Svensson and Drust, 2005). Sprint tests have been shown to discriminate between different standards of players, for example professional players were found to be faster than amateur players over short distances (10 m, 20 m and 30 m) (Kollath and Quade, 1993). Findings of this nature give explanation as to why more coaches consider speed to be the most important physical attribute in elite players. The present results also indicated that coaches, fitness professionals and players believed balance/co-ordination and agility to be important physical attributes in relation to the elite player (Figure 4.1). Interestingly agility has been referred to as the ability to change the direction of the body quickly, being a combination of balance/co-ordination, speed and strength (Draper and Lancaster, 1985). It is has been stated that the fast pace of competitive elite soccer requires players to possess good levels of agility (Svensson and Drust, 2005). Furthermore, it has been suggested that tests of agility provide the clearest differentiation between elite and non-elite players (Reilly et al., 2000). These observations correspond to some extent with the present findings which highlight the perceived importance of balance/co-ordination and agility in elite players.

In contrast to the opinion of coaches, more of the players and fitness professionals thought that endurance, as opposed to speed, was the most important physical attribute in relation to an elite player (Figure 4.1). Some explanation of this finding may be based on the fact that soccer is a high intensity intermittent team sport of 90 minutes duration (Bangsbo, 1994a). During a competitive game elite players cover approximately 10 to 12 km (Ohashi et al., 1988; Bangsbo, Norregaard and Thorsoe, 1991) at an average intensity of 70 to 80% of maximal oxygen uptake ($\dot{V}O_{2max}$) (Helgerud et al., 2001). It has been estimated that during a competitive game aerobic metabolism provides for 90% of the energy cost (Bangsbo, 1994a). For these reasons a high level of endurance fitness (the ability to sustain a high percentage of $\dot{V}O_{2max}$ for a given period of time) has been described as a prerequisite for elite players to compete in the modern game (McMillan et al., 2005). Apor (1988) highlighted the importance of $\dot{V}O_{2max}$ in soccer with the finding that the most successful teams in the Hungarian 1st Division Championship had the highest $\dot{V}O_{2max}$ levels. Furthermore, a high correlation has been observed between the $\dot{V}O_{2max}$ of players and their distance covered during a game in addition to the number of sprints they perform (Smaros, 1980; Helgerud et al., 2001). When the findings of such studies are considered one can appreciate why in the present study that endurance was perceived as being a important attribute in relation to the elite player.

The present study demonstrates the widely held belief that the relative importance of various physical attributes differs in relation to different playing positions (Table 4.3). In support of this finding it has been previously shown that the workload during a game varies significantly between different playing positions (Bangsbo, Norregaard and Thorso, 1991). It is well documented that the demands on goalkeepers, and consequently their training are very different from those of outfield players (Gil et al., 2007). More of the participants in our study regarded agility and balance/co-ordination to be important physical attributes for goalkeepers with fewer participants regarding endurance or speed endurance as being important (Table 4.3). This perception of goalkeepers physical attributes equates to previous observations that goalkeepers possess the lowest $\dot{V}O_{2max}$ values (Davis, Brewer and Atkin, 1992; Tumilty, 1993; Gil et al., 2007). Withers and colleagues (1982) reported that fullbacks sprinted more than twice as much as centrebacks. In line with this finding more of the coaches in our study identified speed and speed endurance as the most important physical attributes associated with a fullback (Table 4.3). In the current study most coaches, fitness professionals and players thought that strength and power were the most important physical attributes that were linked to centrebacks (Table 4.3). In relation to this Stolen and colleagues (2005) suggested that a higher level of strength allows for more powerful jumps, tackles and sprints, all of which are actions commonly associated with playing centreback in a team. The major physical attribute that most coaches, fitness professionals and players related to midfield players was endurance (Table 4.3). In accordance with this finding several studies have reported that the midfield players run the longest distances during a game, acting as a link between defence and attack (Ekblom, 1986; Mohr, Krustrup and Bangsbo, 2003). Furthermore, some studies have found that in terms of playing positions midfield players have the highest $\dot{V}O_{2max}$ values (Rienzi et al., 2000; Wisloff, Helgerud and Hoff, 1998). Speed was identified by most coaches, fitness professionals as the most important physical attribute for forward players (Table 4.3). This perception is in agreement with the findings of Gil and colleagues (2007) where forwards were the fastest players over a 30 m sprint test. The findings of the present study indicate that each playing position is associated with a different physical profile, the relative importance of certain physical attributes varying according to the positional role. This finding would appear to reflect the observations of different physiological workloads related to each playing position during a competitive game (Bangsbo, Norregaard and Thorso, 1991).

The majority of coaches, fitness professionals and players considered that the physical attributes of international and club players differed, with many participants suggesting that international players displayed superior physical characteristics (Figure 4.2). A study comparing graduates from the French National Football Academy found no significant differences to exist in terms of physical performance between those who went on to play international and professional club football (le Gall et al., 2010). In particular our study revealed that international players were considered by many participants to be better in comparison with club players in terms of speed, agility and balance/co-ordination (Figure 4.2). However, with the exception of the study by le Gall and colleagues (2010) few studies to date have compared the physical performance of international and club players in order to confirm or dismiss the perception that international players possess greater physical qualities.

Most coaches (93.5%), fitness professionals (86.6%) and players (83.2%) believed that the physical/physiological attributes of players had become more important over the last 30 years in terms of being successful in the modern game. Two of the main physical characteristics that most participants thought had improved in relation to the modern player were speed and endurance (Figure 4.3). This opinion is supported by suggestions that $\dot{V}O_{2max}$ amongst elite players has been elevated over the last decade compared with those values reported in the 1980s (Stolen et al., 2005). The size of players both in terms of height and body mass was also thought by many participants to have increased over the last 30 years (Figure 4.3). A recent study by Nevill and colleagues (2009) would support this belief, with the finding that professional players were getting taller (1.2 cm) and heavier (1.29 kg) per decade from 1973-74 to 2003-04. Furthermore, it was suggested that successful elite modern players were taller and more linear in their body shape than less successful players (Nevill et al., 2009). Other physical qualities including strength, power and agility were believed by many participants to have improved in relation to elite modern players (Figure 4.3). This may reflect the belief that there is a more systematized approach towards preparing contemporary professional sports personnel for competition than previously (Reilly and Gilbourne, 2003). Moreover, Reilly and Gilbourne (2003) have suggested that the contemporary game at the professional level has become more demanding in a physical context, with players covering more distance in games which are being played at a faster tempo. As a result it is argued that a more systematic approach to training is required in order to meet these elevated demands of the game (Reilly and Gilbourne, 2003).

The current study revealed that Black Caribbean and Black African players were perceived by many participants to be naturally physically advantaged for the purpose of soccer performance (Figure 4.4). In relation to this it is interesting to note the findings of a study by McCarthy and Jones (1997) describing how Black players are portrayed on television. The study revealed that 62% of all the comments made about the physical characteristics of players were made about Black players, with the majority (96%) of these comments being positive. The authors argue that these comments, and the stereotype it suggests, foster this belief of the physically gifted Black player. A limitation that should be highlighted in respect to the study by McCarthy and Jones (1997) is the failure to state what percentage of the players were Black. In the present study the perception of Black players being more physically able was especially related to the attributes of speed, power and strength (Figure 4.5). For example, in the television footage analysed by McCarthy and Jones (1997) Sol Campbell was referred to as “a powerhouse of a figure”, Michael Duberry was described as “such a strong player in defence” and Les Ferdinand was portrayed as being “big, strong, quick, powerful, with the ability to hang in the air”. Apparent racial stereotyping of this nature has also been reported in relation to the performance of Black athletes by the American sports media (Sage, 1990). It is suggested that the achievements of Black athletes has frequently been attributed to “their ‘natural’ abilities to run fast” (Sage, 1990). The stereotypes regarding the Black player have been implicated in selection for certain playing positions and the associated concepts of ‘stacking’ and ‘centrality’ that have been shown to exist in English football (Maguire, 1991). McCarthy and Jones (1997) make the point that descriptions of players occupying non-central positions, for example on the ‘wing’ (wide attacking position), are made in relation to the positions that are traditionally associated with strength and speed. This raises the question as to whether such descriptions are of the player or the position, with the ethnicity of the player being incidental. Despite this it is argued that the over-representation of Black players in non-central roles is created by the stereotypes relating to their physical attributes which ensures that the perceived requirements of the position and the image of the Black player are mutually reinforced (McCarthy and Jones, 1997).

The present study indicates the importance placed on physical performance testing in soccer, with 97% of the coaches questioned deeming testing to be important. It was considered important to test a number of different physical attributes, although more coaches thought speed was very important to test (Figure 4.6). The fact that the physiological demands of soccer require players to be competent in several aspects of fitness may reflect why testing a number of different physical attributes, including strength, power and agility was regarded as important. The additional importance placed on testing speed would appear to relate to the general consensus that speed is a key component of success in elite soccer. Speed or more precisely the ability to accelerate often decides crucial outcomes of the game (Svensson and Drust, 2005). A high $\dot{V}O_{2max}$ has been referred to as a hallmark of well-trained elite players (Reilly and Gilbourne, 2003). For example, Wisloff and colleagues (1998) noted that players from a top ranked Norwegian team had higher $\dot{V}O_{2max}$ values than players from a lower ranked team competing in the same league (67.6 vs. 59.9 $ml.kg^{-1}.min^{-1}$). Observations of this nature may explain why the testing of endurance in the current study was viewed as very important by more fitness professionals and players.

The current investigation revealed that some coaches (40.2%), fitness professionals (47.3%) and players (56.6%) were of the opinion that accurate assessments of a players physical attributes could be made from observing a game. Speed and endurance were the two attributes which were considered by most participants to be the most assessable whilst observing a game (Figure 4.7). In terms of talent identification the majority of professional soccer clubs rely on subjective assessments of this nature made by scouts or coaches. Subjective assessments of this nature are often supported by key criteria, for example, TABS (Technique, Attitude, Balance and Speed), SUPS (Speed, Understanding, Personality, Skill) and TIPS (Talent, Intelligence, Personality, Speed) (Williams and Reilly, 2000). The fact that speed is the one physical attribute that is present in each assessment criteria described by Williams and Reilly (2000) further emphasises the importance placed on speed in the modern game. In the present study the majority of coaches (75.0%), fitness professionals (65.7%) and players (60.2%) indicated that objective measurements taken from physical performance tests offered a more accurate assessment of physical performance than subjective observations made during a game. In relation to this, Williams and Reilly (2000) suggest that physical performance testing can add a degree of objectivity to the process of talent identification. They further state that objective data from physical performance tests can be used to help confirm scouts' and coaches' initial intuition with regards to players' strengths and weaknesses. Some studies have indicated that physical performance measures can be used to identify potential elite players (Jankovic et al., 1993; Janssens et al., 1998). For example, a study of 47 Croatian soccer players aged 15 to 17 years by Jankovic and colleagues (1993) demonstrated that successful players who were later selected to play in top European leagues possessed higher levels of $\dot{V}O_{2max}$ than their less successful peers who went on to play at a regional level.

The present study highlights the importance of physical performance testing in soccer. It was suggested that the objective information provided could be used for talent identification, identifying strengths and weaknesses, monitoring progress and development, motivating players and identifying a player's suitability for different playing positions (Figure 4.8). Svensson and Drust (2005) also referred to how the information from physiological testing can provide individual profiles of players' respective strengths and weaknesses. Previously Balsom (1994) described how objective information was required on changes in performance over time in order to analyse the effectiveness of training programmes and to assess an individual players readiness to return to training and games following a period of rehabilitation. Furthermore, it has been suggested that information from physical performance tests provides useful feedback to coaches and trainers on the effectiveness of intervention programmes and the responses of individuals to such programmes

(MacDougall and Wenger, 1991). Based on our observations and those of other authors it is apparent that physical performance testing in the soccer environment provides important information which can be used to add an element of objectivity to a number of the decision making processes that are made by coaches and trainers within the game in relation to players.

This study shows that both laboratory and field-based tests were considered to be valuable/useful tools of physical assessment in the soccer environment, although a slightly more coaches, fitness professionals and players thought field tests were more use/valuable than laboratory tests (Figure 4.9). The main benefit of laboratory tests relates to the controlled environment in which they are undertaken where the impact of extraneous variables is limited in order to provide accurate information (MacDougall and Wenger, 1991). A number of problems have been highlighted in relation to laboratory testing, including access to facilities, expense and their time consuming nature (Svensson and Drust, 2005). The current study confirms these observations, as a lack of time, facilities/equipment, expertise as well as cost were considered to be some of the main problems associated with physical performance testing (Table 4.5). The fact that slightly more participants thought field testing to be more valuable/useful as opposed to laboratory testing may relate to the fact that field tests can be carried out with minimal equipment and cost within the soccer training environment. In addition to this it has been argued that physical performance tests conducted in the field enhance the specificity and therefore the validity of the evaluations (Balsom, 1994). Furthermore, it is suggested that using field tests to evaluate specific aspects of soccer performance may provide a better indication of the ability to perform during a game than laboratory based evaluations (Svensson and Drust, 2005).

In summary, the present study has highlighted the importance placed on the physical aspects of performance and the testing of physical aspects of performance in elite soccer by coaches, fitness professionals and players. The information provided by physical performance tests, in particular those conducted in the field as opposed to the laboratory, was believed to assist with various processes including talent identification and monitoring player progress and development within the elite soccer setting.

4.4.1 Practical applications

This study provides a basis for understanding how physical aspects of performance in soccer are perceived by practitioners (coaches and fitness professionals) and players. A detailed insight is provided with regards to how practitioners beleive physical performance testing is best utilised within the elite soccer setting. The information presented in this study will help direct the practitioner in terms of the aspects of physical performance that are considered to be important in terms of player assessment and the nature of the tests that are thought to be best suited to assessing players in the professional soccer club environment.

CHAPTER 5
PHYSICAL PERFORMANCE TESTS VALIDITY AND RELIABILITY

5.1 INTRODUCTION

Researchers have investigated various physical, physiological and anthropometric characteristics of elite players (Reilly et al., 2000; Reilly, 1994a; Rienzi et al., 2000). Many of the initial studies relating to the physical performance characteristics of soccer players employed laboratory based tests (Faina et al., 1988; Tumilty, 1993), but as has been suggested in the previous chapter and by other authors that laboratory based measurements are less accessible, often too expensive and produce results that are unclear in terms of their implications for physical performance (Alricsson and colleagues, 2001). Today, practitioners working with squads more often adopt soccer specific field-based tests, allowing greater numbers of players to be tested (Reilly and Gilbourne, 2003). Indeed, evidence presented in the previous chapter (Chapter 4) suggests that practitioners involved in the game at the elite level place more value on field-based performance tests as opposed to laboratory based assessments (Figure 4.9). It is paramount however that any field-based performance tests that are employed are both valid and reliable (Atkinson and Nevill, 1998).

There has been an increase in the literature relating to the importance of validity and reliability studies and the statistics that should be employed and interpreted (Atkinson and Nevill, 1998). To conclude that a test is valid it must show logical and construct validity; criterion validity should also be demonstrated for tests where an established ‘gold standard’ test exists (Strand and Wilson, 1993). Logical validity assesses whether a test measures what it intends to measure, but it has been suggested that this can be something that is difficult to truly assess (Thomas and Nelson, 1990). Construct validity relates to whether a test is able to discriminate between different groups of performers (Strand and Wilson, 1993). Criterion validity allows for an objective measure of validity (Currell and Jeukendrup, 2008) of which there are two types, concurrent and predictive (Thomas and Nelson, 2001). Concurrent validity means that the performance protocol is correlated with a criterion measure, whilst predictive validity involves using a performance protocol to subsequently predict performance (Thomas and Nelson, 2001).

In addition to being valid a test must be reliable which has been defined as 'the consistency of an individual's performance on a test' (Atkinson and Nevill, 1998). Baumgarter (1989) identified two types of reliability, absolute and relative. Absolute reliability is the extent to which repeated measurements vary for individuals and can be expressed as either actual units of measurement or as a proportion of the measured values (Atkinson and Nevill, 1998). Relative reliability is the extent to which individuals maintain their position in a sample with repeated measurements and is usually assessed with some form of correlation coefficient (Atkinson and Nevill, 1998). All tests include some degree of measurement error and therefore reliability should be considered as the amount of measurement error that is deemed acceptable for the effective practical use of a test. When the test is to be used for scientific research, the acceptable level is of paramount importance (Sunderland et al., 2006).

The aim of this study was to design a battery of soccer specific functional field tests, which would be both valid and reliable for use in the modern game of soccer and determine the biological and technical variation of the field tests in order to assess their suitability as a tool to use for research within the soccer club environment. The hypothesis to be tested was that physical based field tests provide a valid and reliable tool for the assessment of physical/physiological performance characteristics in elite young players.

5.2 METHODS

5.2.1 Validity of physical performance tests

5.2.1.1 Logical validity

To establish the logical validity of the physical performance tests, 443 questionnaires relating to physical performance and testing in soccer were administered to coaches (n=170), fitness professionals (sports scientists;

strength and conditioning coaches, and physiotherapists) (n=172) and players (n=101) (as reported in full in Chapter 4).

5.2.1.2. Construct validity

Construct validity was determined by two methods. Firstly the field test performance of players' (as described in section 3.4) was compared between three different ability groups of players, with the coaches' scoring players in relation to their 'global soccer ability' (1 – above average for academy age group (n=27); 2 - average for academy age group (n=50); 3 – below average for academy age group (n=3)). Secondly the players' performance on the physical field tests as (described in section 3.4) was compared between different age groups, U9s-U11s (n=29); U12s-U14s (n=26); U15s-U18s (n=25).

5.2.2 Reliability of physical performance tests

5.2.2.1 Participants

Eighty elite young soccer players (age 13.2 ± 2.6 years; height 158.7 ± 17.6 cm; body mass 50.6 ± 17.1 kg) participated in the reliability study. All the subjects were registered at the same professional soccer club academy in England.

5.2.2.2 Procedures

To examine the reliability of the performance based field tests, participants completed two testing sessions conducted 7 days apart during the 2004-2005 playing season. A detailed description of the procedures and physical performance testing protocol can be found in sections 3.3 and 3.4.

5.2.3 Statistical analysis

Data were analysed using SPSS (Version 16.0, Chicago, Illinois, USA). The validity and reliability of the physical performance tests was determined using a number of statistical techniques including, intraclass correlation (ICC), Bland and Altman limits of agreement (Bland and Altman, 1986), typical error (Hopkins, 2000), repeatability (Bland and Altman, 1996), within-subject coefficient of variation, two-way analysis of variance (ANOVA) and paired *t*-

test. Statistical significance was accepted at the 95% confidence level ($p<0.05$). Values are reported as mean (±SD).

5.3 RESULTS

5.3.1 Validity of physical performance tests

5.3.1.1 Logical validity

In total 97% of the coaches considered physical performance testing to be an important aspect of preparation, along with fitness professionals (94%) and players (83%). In general, it was considered important to test all physical attributes (‘strength’; ‘power’; ‘endurance’; ‘speed’; ‘agility’; ‘balance and co-ordination’; ‘speed endurance’), (Figure 4.6). Coaches viewed speed and balance and co-ordination as the most important attributes to test, compared to fitness professionals who viewed endurance and speed to be most important, with players viewing endurance and speed endurance as the most important attributes to test (Figure 4.6).

5.3.1.2 Construct validity

i. Differences between age groups

The heart rate response to the same running speed during the MSFT was highest in the U9s-U11s and lowest for the U15s-U18s, with all comparisons statistically significantly different with the exception of level 1 ($p<0.05$; Figure 5.1). Recovery heart rate however did not differ between the age groups with the exception of a lower recovery heart rate for the U15s-U18s compared to the U9s-U11s at 120 s ($p<0.05$). The vertical jump, speed and agility test results for each age group are shown in Figure 5.2. As the age of the respective players’ increased, vertical jump, speed and agility test performance improved ($p<0.01$; Figure 5.2).

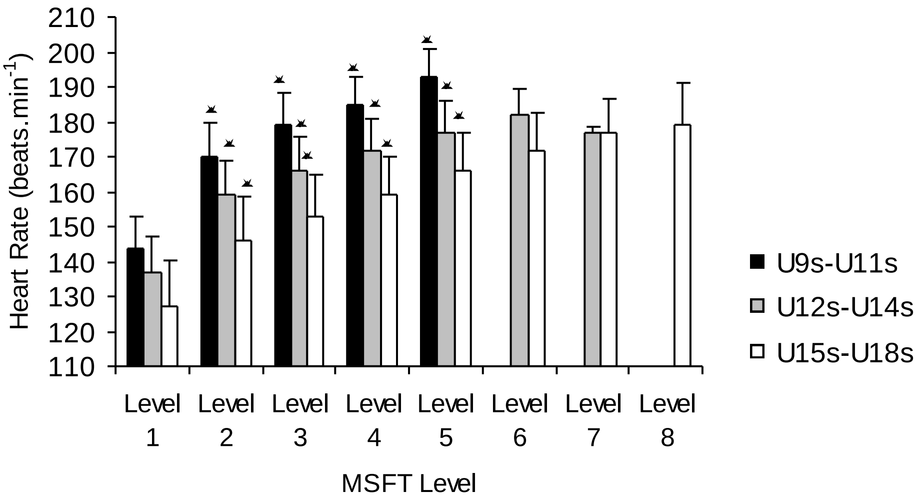


Figure 5.1. Age group heart rate values for MSFT levels (Test 1 and 2 mean±SD).
*p<0.05; main effect age group

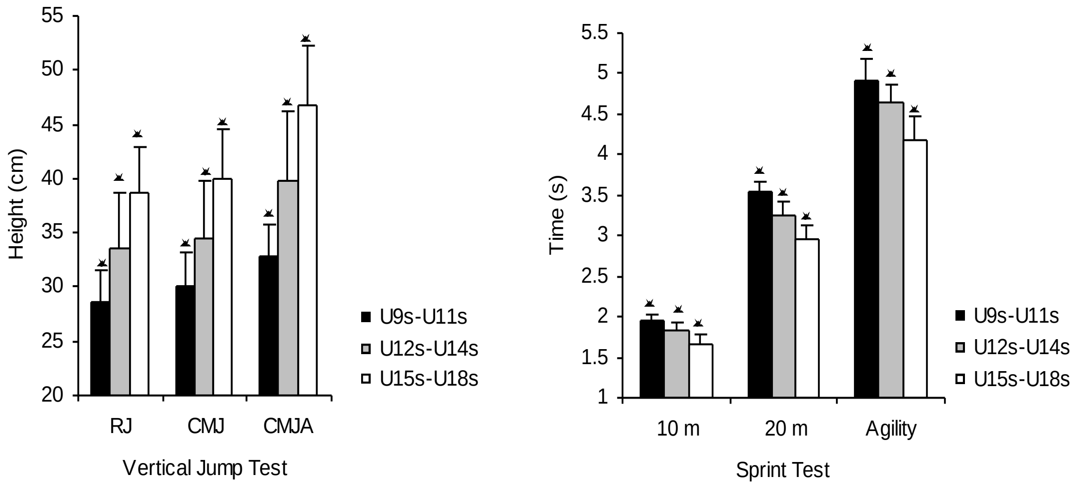


Figure 5.2. Age group data for vertical jump, speed and agility tests (Test 1 and 2 mean±SD).
*p<0.01; main effect age group

ii. Differences between ability groups

The heart rate response on the MSFT of players classified by the coach as 'above average' (n=17) and 'average' (n=33) is shown in Figure 5.3. Only 3 players were classified as 'below average' and are not included in the analysis. No significant differences were apparent for heart response to the MSFT or heart rate recovery values between different playing ability groups (main effect ability group: N.S.; Figure 5.3). However, in general heart rate values on the MSFT were lower in the 'above average' players with the exception of heart rate values for level 8 (Figure 5.3). The vertical jump, speed and agility test results for each ability group are shown in Figure 5.5. Players classified as 'above average' outperformed those classified as 'average' on the jump, speed and agility tests (p<0.05; Figure 5.4). The average sum of ranks on all physical performance tests was lower for the 'above average' compared to the 'average' players, indicating the better physical performance of the 'above average' players (Figure 5.5).

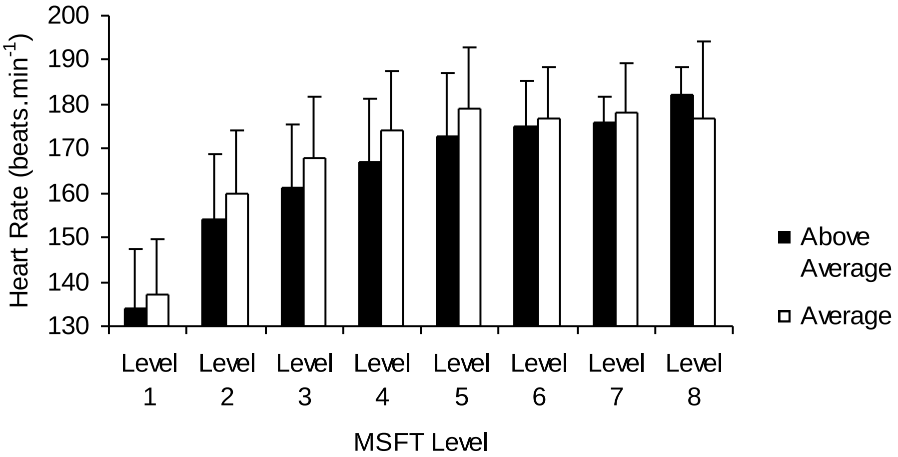


Figure 5.3. Ability group heart rate values for MSFT levels (Test 1 and 2 mean±SD).
N.S.; main effect ability group

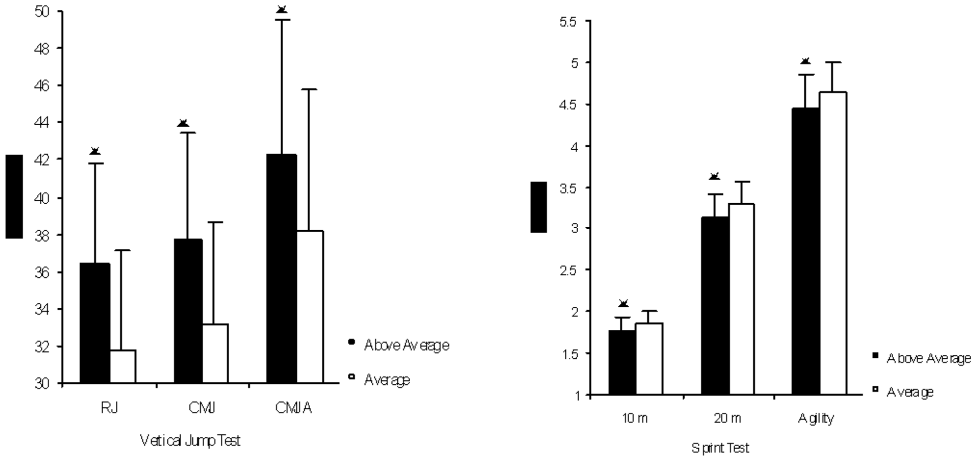


Figure 5.4. Ability group data for jump, speed and agility tests (Test 1 and 2 mean±SD).
*p<0.05; ‘above average’ vs. ‘average’

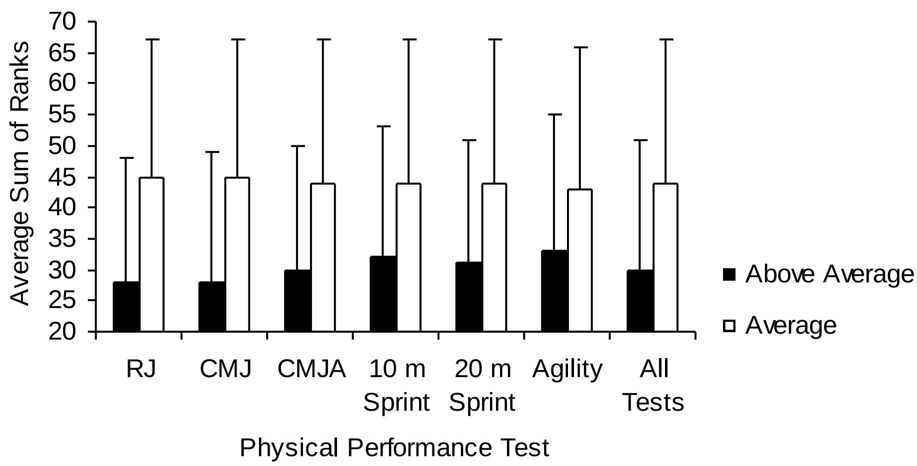


Figure 5.5. Average sum of ranks on jump, speed and agility tests for ability groups (mean±SD).

5.3.2 Reliability of physical performance tests

5.3.2.1 Heart rate response to MSFT

Heart rate data was successfully recorded for 52 players. Heart rate values on the MSFT with the exception of level 8, and recovery heart rate values were lower in the second testing session by an average of 3-4 beats.min^{-1} (main effect test 1 vs. test 2; $p<0.05$). The limits of agreement varied from a high of 12.9 beats.min^{-1} for level 1 to a low of 5.2 beats.min^{-1} for level 7, indicating that there was less variability in the heart rate response between the two tests as exercise intensity increased. Reliability analysis conducted within different age groups indicated similar differences in the heart rate response to the MSFT and recovery heart rate values to exist between test 1 and 2.

Intraclass correlation coefficient (ICC) and pearson product moment correlation (PCC) were used to assess the relative reliability, being >0.94 for the heart rate response to MSFT levels 2 to 8 and the peak heart rate value. The ICC and PCC for the heart rate response to level 1 of the MSFT and the heart rate values after 60 and 120 s recovery were between 0.80 and 0.90. The percentage heart rate recovery values after 60 and 120 s were <0.80.

5.3.2.2 Vertical jump, speed and agility tests

Table 5.1 shows absolute and relative reliability measures of the physical performance tests. The average values for the performance tests, with the exception of the agility test, show a small systematic bias of performance being worse in the second test. A paired *t*-test comparing the means of test 1 and test 2 in all performance tests indicated significant differences in sprint (10 and 20 m) and agility test performance ($p<0.05$; Table 5.1). These differences were however minimal, with the 10 m and 20 m sprint being 0.01 and 0.03 s slower in test 2, respectively, with the agility test being 0.04 s faster in test 2. No significant differences (paired *t*-test) were observed in jump test performance between test 1 and test 2 ($p<0.05$; Table 5.1).

The repeatability (Bland and Altman, 1996) of the vertical jump tests ranged from 3.2 to 3.5 cm for the RJ and CMJA, respectively. On the sprint tests repeatability ranged from 0.07 s on the 10 m sprint to 0.24 s for the agility test, respectively (Table 5.1). Within-subject coefficient of variations were less than 3.7% for the vertical jump tests and 1.9% for the sprint tests (Table 5.1).

Reliability analysis conducted within different age groups indicated greater differences in performance between test 1 and 2 to exist in the U9s-U11s than any other age group (Table 5.2 and 5.3). A paired *t*-test indicated significant differences in the U9s-U11s performance between test 1 and test 2 to be evident on the CMJA, 20 m sprint and agility tests ($p<0.05$; Tables 5.2 and 5.3). CMJA was 0.7 cm lower, 20 m sprint 0.03 s slower and agility 0.05 s faster in test 2 for the U9s-U11s (Tables 5.2 and 5.3). However, for the U15s-U18s there were no significant differences between test 1 and 2 except for the 20 m sprint which was 0.02 s slower on the second test ($p<0.05$; Table 5.3).

ICC and PCC values to assess the relative reliability of the performance tests were all ‘high’ (>0.90) ranging from 0.96 for the agility test to 0.99 for the 20 m sprint (Tables 5.2 and 5.3). When relative reliability was analysed in relation to age group the lowest ICC and PCC values were found in the U9s-U11s, ranging from 0.84 to 0.92 for the CMJ and 20 m sprint, respectively. The highest ICC and PCC values were established in the U15s-U18s, ranging from 0.92 to 0.97 for the RJ and 10 m sprint, respectively. These results suggest that the relative reliability of the tests is better for older players.

Table 5.1. Absolute and relative reliability measures of the physical performance tests.

	RJ (cm)	CMJ (cm)	CMJA (cm)	10 m Sprint (s)	20 m Sprint (s)	Agility (s)
Test 1 (X±SD)	33.4±5.7	34.8±6.0	33.4±5.7	1.83±0.15	3.25±0.29	4.62±0.41
Test 2 (X±SD)	33.3±6.0	34.5±5.9	33.3±6.0	1.84±0.15	3.27±0.29	4.57±0.39
ICC	0.96	0.96	0.97	0.98	0.99	0.96
PCC	0.96	0.96	0.97	0.98	0.99	0.96
95% CI	0.94 to 0.98	0.94 to 0.97	0.96 to 0.98	0.96 to 0.99	0.98 to 0.99	0.94 to 0.97
α	0.98	0.98	0.97	0.99	0.99	0.98
Mean Diff ± LoA	-0.04±3.2	-0.23±3.3	-0.38±3.5	0.01±0.06	0.03±0.10	-0.04±0.23
% Rel	4.95	4.93	4.47	1.79	1.56	2.56
SEM	0.184	0.191	0.197	0.004	0.006	0.013
Typical error (%)	1.2	1.2	1.2	0.02	0.04	0.08
sw*2.77	3.2	3.3	3.5	0.07	0.11	0.24
CV (%)	3.5	3.7	3.3	1.3	1.2	1.9
t-test	0.839	0.242	0.060	0.013*	0.001*	0.002*

*Significant difference test 1 vs. test 2.

Table 5.2. Absolute and relative reliability measures for jump tests by age group.

	RJ (cm)			CMJ (cm)			CMJA (cm)		
	U9s-U11s	U12s-U14s	U15s-U18s	U9s-U11s	U12s-U14s	U15s-U18s	U9s-U11s	U12s-U14s	U15s-U18s
Test 1 (X±SD)	28.6±3.1	33.6±4.9	38.6±4.1	30.2±3.2	34.6±5.3	40.2±4.7	33.1±3.2	39.7±6.6	46.9±5.5
Test 2 (X±SD)	28.6±3.1	33.6±5.3	38.5±4.7	30.0±3.3	34.5±5.3	39.8±4.4	32.5±3.1	39.7±6.5	46.4±5.8
ICC	0.878	0.943	0.920	0.841	0.957	0.926	0.890	0.964	0.935
PCC	0.879	0.945	0.929	0.842	0.957	0.928	0.891	0.964	0.936
95% CI	-0.514 to 0.652	-0.738 to 0.0661	-0.644 to 0.804	-0.557 to 0.833	-0.479 to 0.787	-0.325 to 1.125	0.96 to 1.215	-0.747 to 0.670	-0.364 to 1.324
α	0.935	0.970	0.958	0.914	0.978	0.961	0.942	0.982	0.966
Mean Diff ± LoA	0.07±3.0	-0.04±3.4	0.08±3.4	0.14±3.5	0.15±3.1	0.40±3.4	0.66±3.0	-0.04±3.4	0.48±4.0
% Rel	5.37	5.15	4.55	5.92	4.54	4.39	4.71	4.42	4.38
SEM	0.285	0.340	0.351	0.339	0.307	0.351	0.273	0.344	0.409
Typical error (%)	1.08	1.22	1.24	1.29	1.11	1.24	1.04	1.24	1.45
sw*2.77	3.0	3.3	3.4	3.5	3.0	3.5	3.1	3.4	4.0
CV (%)	3.8	3.6	3.2	4.3	3.4	3.2	3.4	3.3	3.1
t-test	0.810	0.911	0.822	0.687	0.621	0.266	0.023*	0.912	0.252

*Significant difference test 1 vs. test 2.

Table 5.3. Absolute and relative reliability measures for sprint tests by age group.

	10 m Sprint (s)			20 m Sprint (s)			Agility (s)		
	U9s-U11s	U12s-U14s	U15s-U18s	U9s-U11s	U12s-U14s	U15s-U18s	U9s-U11s	U12s-U14s	U15s-U18s
Test 1 (X±SD)	2.0±0.1	1.8±0.1	1.7±0.1	3.5±0.1	3.2±0.2	2.9±0.2	4.9±0.3	4.7±0.2	4.2±0.3
Test 2 (X±SD)	2.0±0.1	1.8±0.1	1.7±0.1	3.6±0.1	3.3±0.2	3.0±0.2	4.9±0.3	4.6±0.2	4.2±0.3
ICC	0.858	0.948	0.967	0.915	0.957	0.963	0.896	0.867	0.934
PCC	0.864	0.957	0.968	0.919	0.963	0.963	0.899	0.867	0.934
95% CI	-0.202 to 0.008	-0.024 to 0.000	-0.024 to 0.002	-0.047 to -0.005	-0.046 to -0.006	-0.044 to -0.003	-0.000 to 0.951	0.018 to 0.111	-0.034 to -0.056
α	0.924	0.973	0.983	0.955	0.978	0.981	0.945	0.929	0.966
Mean Diff ± LoA	-0.01±0.07	-0.01±0.06	-0.01±0.06	-0.03±0.11	-0.03±0.10	-0.02±0.10	0.05±0.24	0.06±0.23	0.01±0.21
% Rel	1.91	1.60	1.88	1.57	1.50	1.68	2.54	2.49	2.60
SEM	0.007	0.006	0.006	0.010	0.010	0.010	0.023	0.023	0.022
Typical error (%)	0.03	0.02	0.02	0.04	0.03	0.04	0.09	0.08	0.08
sw*2.77	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.3	0.2
CV (%)	1.4	1.2	1.4	1.2	1.2	1.3	1.9	2.0	1.8
t-test	0.397	0.052	0.108	0.017*	0.012*	0.025*	0.049*	0.009*	0.631

*Significant difference test 1 vs. test 2.

5.4 DISCUSSION

One of the main aims of the study was to develop a valid battery of specific physical performance field tests for use with soccer players. Logical validity of the battery of tests adopted during the study was determined from the questionnaire responses of coaches, fitness professionals and players. The questionnaire highlighted the importance of testing a number of different physical attributes, including, strength, power, endurance, speed, agility, balance and co-ordination and speed endurance. Currell and Jeukendrup, (2008) suggest that for a performance testing protocol to be a logically valid measure of performance, it must appear to measure the performance in question. In the present study the questionnaire responses of coaches, fitness professionals and players were used to establish the performance in question, namely the physical aspects of soccer which were deemed important to test. Therefore, the tests included in the physical performance test battery employed in the current study can be considered as logically valid as they examine physical aspects of soccer that have previously been identified as the performance in question. For example, a 10 m and 20 m sprint test was used in the present study and a number of coaches thought that it was 'very important' to test speed (Figure 4.6).

Construct validity was demonstrated as all the jump, speed and agility tests employed were shown to discriminate between the physical performances of different age groups of players. The highest level of physical performance on these tests was observed in the oldest players (U15s-U18s), with the lowest level of physical performance being associated with the youngest players (U9s-U11s) ($p<0.01$). The heart rate response to the MSFT also distinguished between different age groups of players. Heart rate for a given running speed was found to decrease with increasing age, with the exception of level 1 where no difference was observed between the U9s-U11s and U12s-U14s. Conversely, the recovery heart rate values did not distinguish between different age groups of players, and therefore cannot be considered a valid measurement tool.

The construct validity of the tests was further underlined by their ability to distinguish between different levels of playing ability. Players who coaches classified as 'above average' for their academy age group in terms of 'global soccer ability' outperformed those classified as 'average' on the jump, speed and agility tests ($p<0.05$). Although no differences were found in the heart rate response to the MSFT for players with different levels of ability, there was a tendency for the respective heart rate values to be lower in the 'above average' compared with the 'average' players. Based on the assumption that heart rate decreases at a sub-maximal exercise intensity with increasing endurance fitness (Wilmore et al., 1996), the tendency for lower heart rate values in the 'above average' players may suggest a higher level of endurance fitness compared to the 'average' players.

It has previously been observed that tests performed in the field enhance the specificity of the evaluation (Svensson and Drust, 2005). Furthermore it is suggested that this greater specificity increases the validity of field tests (MacDougall and Wenger, 1991; Balsom, 1994). The specific nature of the field-based tests conducted in the present study would appear to have contributed to their validity as a tool of physical evaluation. For example, the test of agility used in the current study where players cover a total distance of 20.8 m is in accordance with the average distance (19.0 ± 9.0 m) reported to be covered by soccer players during a sprint in a game, (Strudwick and Reilly, 2001). In comparison the 'T test' which has previously been shown to be a reliable and popular assessment of agility is 36.56 m in length (Pauole et al., 2000) far greater than average sprint distance reported for players during a game (Strudwick and Reilly, 2001). Based on this observation, the test of agility used in the current study would appear to be a more specific and valid test of agility for soccer players.

It has previously been suggested that the Bland and Altman limits of agreement approach be used to assess absolute reliability of physical performance tests (Atkinson and Nevill, 1998). The heart rate response to the MSFT suggests that absolute reliability improves as the level of exercise intensity increases. The mean differences observed in heart rate response to the MSFT (ranging from 2.4 ± 6.8 beats.min^{-1} to 3.8 ± 8.9 beats.min^{-1} on level 8 and 5, respectively) demonstrated a superior level of absolute reliability than recovery heart rate values (4.4 ± 13.7 beats.min^{-1} and 3.8 ± 11.8 beats.min^{-1} after 60 and 120 s, respectively). These findings are supported by the suggestion that heart rate varies more during lower exercise intensities and recovery periods, and least at higher exercise intensities (~90% of maximum) (Lamberts et al., 2004). Achten and Jeukendrup (2003) state that even under controlled conditions, changes of 2-4 beats.min^{-1} are likely to occur when individuals are measured on different days.

An ICC of over 0.90 is considered to be ‘high’, between 0.80 – 0.90 ‘moderate’, and below 0.80 ‘insufficient’ for physiological field tests (Vincent, 1995). The heart rate response to the MSFT demonstrated a ‘high’ level of relative reliability with the exception of level 1 which was only ‘moderate’. The range in ICC values, (0.880 to 0.988 on MSFT level 1 and 3, respectively) was lower than the test retest correlations (0.97 – 0.99) recently reported by Lamberts and colleagues (Lamberts et al., 2004), but slightly higher than the value of 0.87 previously established by Becque and colleagues (1993). Only a ‘moderate’ level of relative reliability was found for the 60 and 120 s recovery heart rate values (0.81), whilst the 60 and 120 s % heart rate recovery values were ‘insufficient’ in terms of test retest reliability. These findings differ from those of Lamberts and colleagues (2004) who describe a ‘high’ level of relative reliability for both recovery heart rate values and % heart rate recovery. Unlike the continuous nature of the MSFT used in the present study, Lamberts and colleagues (2004) used a sub-maximal shuttle test of increasing intensity interspersed with recovery periods which may explain the differing findings between the respective studies.

The mean difference and limits of agreement was similar for all three jump tests, ranging from 0.04 ± 3.2 cm and 0.35 ± 3.5 cm for the RJ and CMJA, respectively. The vertical jump tests also displayed a ‘high’ level of relative reliability with ICC values ranging from 0.96 (CMJ) to 0.97 (CMJA). These findings are similar to those of Markovic and colleagues (2004), who concluded that CMJ and RJ are the most reliable and valid field tests for the estimation of explosive power of the lower limbs in physically active men. Furthermore, Hopkins and colleagues (2000) suggest that the best measure of explosive iso-inertial exercise is distance or height in a simple test of jumping.

The mean difference and limits of agreement was also similar for the 10 m and 20 m sprints, -0.01 ± 0.06 s and 0.03 ± 0.05 s, but slightly higher for the agility test, 0.04 ± 0.23 s. In percentage terms the sprint tests displayed a greater level of reliability than the jump tests, ranging from 1.79 to 2.56% (10 m sprint and agility) compared to 4.52

to 4.95% (CMJA and RJ), respectively. Significant differences were however found to exist between test 1 and 2 for the sprint and agility tests which may be taken to suggest that two trials are not sufficient to assess reliability. However, these findings may be a result of the relatively large sample size used in this study. Furthermore, the repeatability analysis suggested acceptable levels of measurement error to exist. For example the difference between two performances on the 10 m sprint would be expected to be separated by 0.07s or less for 95% of testing occasions. Within-subject coefficient of variation of less than 2% for the sprint and agility tests also suggests a good level of reliability. Furthermore, the sprint tests (10 m and 20 m) demonstrated the highest level of relative reliability compared to all other tests, with ICC values of 0.98 and 0.99, respectively.

It has been reported that the sense of balance is not fully developed in 8-year old gymnasts (Peltenburg et al., 1982), with balance abilities being related to speed, agility and rhythm (Sanborn and Wyrich, 1969). Since our battery of football related functional tests emphasise speed and agility the reliability of all tests was analysed within different age groups (U9s-U11s; U12s-U14s; U15s-U18s). No difference in the absolute reliability of the tests within the different age groups was evident. However, higher levels of relative reliability were evident in the older age groups. In the U9s-U11s only the 20 m sprint had an ICC >0.90, the other tests ranging from 0.84 to 0.90, which can only be considered as a 'moderate' correlation. In contrast the ICC values for all tests in the U12s-U14s and U15s-U18s were >0.90, demonstrating a 'high' level of correlation.

Other characteristics of the participant group including heterogeneity, motivation to do well, and learning capabilities are assumed to be factors that affect reliability in a positive manner (Baumgarter and Jackson, 1999). Hopkins and colleagues (2001) also suggest that athletes are more reliable than non-athletes given their frequent exposure to training and competition and therefore lower variability of performance. The participants used in the present study were a homogenous and highly motivated group and were perceived to have above average learning capabilities, all playing football at the highest junior club level. Environmental conditions do influence field testing (Baumgarter and Jackson, 1999). To minimise any environmental influence all tests were conducted in a sports hall where differences in ambient temperature and relative humidity were minimal. Furthermore, tests were conducted on the same new generation artificial surface on which the participants regularly trained, allowing normal playing footwear to be worn for all performance tests.

Based on the multitude of methods of validity and reliability assessment used in the present study, with the exception of the heart rate recovery values, all the physical field-based performance tests demonstrated logical and construct validity, and were shown to be a reliable and objective tool for assessing young elite soccer players.

5.4.1 Practical applications

This study provides the practitioner with details of a battery of soccer specific functional field tests, which are both valid and reliable for use in the modern game of soccer. Information on the biological and technical variation of the field tests confirms their suitability as a tool to use for player assessment and research purposes. The functional and specific nature of the field tests make them ideal for use in the soccer club environment in which players are familiar. As the tests are quick and easy to administer they allow squads of players to be assessed in one session and can therefore be more easily incorporated into what can often be a demanding schedule of playing and training commitments.

CHAPTER 6

THE YOUNG ELITE SOCCER PLAYER

6.1 ANTHROPOMETRIC AND PHYSICAL PERFORMANCE CHARACTERISTICS OF ELITE CHILD AND ADOLESCENT SOCCER PLAYERS

6.1.1 INTRODUCTION

In recent years there has been a lot of interest in youth soccer much of which has focused on the identification and development of talented players at a young age (Stratton et al., 2005). It is acknowledged that predicting a players' performance potential at an early age is complex (Reilly, Bangsbo and Franks, 2000), despite this researchers have endeavored to identify characteristics that predispose players for elite soccer, with a great deal of the focus being on anthropometric and physical performance characteristics (Jankovic et al., 1993; Franks et al., 2002; Mujika et al., 2009; le Gall et al., 2010).

The majority of the research on physical performance that has been conducted with elite young players has predominantly concentrated on players during the later stages of their development, for example, U18s (Leatt, Shephard and Plyley, 1987), U16s and U18s (Jankovic et al, 1993), U16s (Franks et al., 2002), U14s, U15s and U16s (le Gall et al., 2010) and U19s (Mujika et al., 2009).

In England the advent of soccer academies has seen elite players being recruited to professional clubs at even younger ages, with teams ranging from U9s through to U19s. To date few studies relating to anthropometric and physical performance characteristics have been carried out on elite young players during the early stages of their development. Furthermore, thus far no studies have reported on the anthropometric and physical performance characteristics of elite young players throughout the full spectrum of youth football, in squads ranging from U9s to U19s.

Therefore, the purpose of this study was to investigate the anthropometric and physical performance characteristics of elite child and adolescent players associated with professional clubs in England using tests that have previously been shown to be valid and reliable (Chapter 5) and establish normative data and performance standards for these players. The hypothesis to be tested was that the physical performance of elite young players in professional English soccer academies improves with chronological age from the under 9 to under 19 years age group squads.

6.1.2 METHODS

6.1.2.1 Participants

Participant information is provided in section 3.3.4.

6.1.2.2 Procedures

A detailed description of the procedures and physical performance testing protocol can be found in sections 3.3 and 3.4.

6.1.2.3 Statistical analysis

Data were analysed using SPSS (Version 16.0, Chicago, Illinois, USA). Descriptive statistics were calculated. The age at peak height velocity (PHV) and peak weight velocity (PWV) was calculated as the mid-point between the two age groups where the greatest increase in standing height and body mass was observed (Table 6.1.1). One-way analysis of variance (ANOVA) was used to investigate differences in anthropometric and physical performance variables between the different age groups. When a significant age group effect was found a Tukey post hoc test was used to test differences among means. Pearson correlation coefficients (r) were calculated to determine the statistically significant relationships ($p<0.01$) between the different measurements of physical performance. Standing height and body mass measurements were compared against British 1990 growth reference centiles (Cole et al., 1998) using the LMS method (Cole and Green, 1992). Statistical significance was accepted at the 95% confidence level ($p<0.05$). Values are reported as mean ($\pm$SD).

6.1.3 RESULTS

6.1.3.1 Anthropometric characteristics

The large ranges reported for standing height and body mass indicate the heterogeneous nature of the group of players involved in the present study, (Table 6.1.1). PHV and PWV occurred at 13.7 years of age (between the U13 and U14 age groups), ~9.0 $cm.yr^{-1}$ and 8.6 $kg.yr^{-1}$, respectively (Table 6.1.1). Significant year-on-year increases in standing height (9.2 to 16.1 years) and body mass (9.2 to 17.2 years) were observed ($p<0.01$; Table 6.1.1). The significant increase in body mass index values occurred between 13.2 and 16.1 years of age ($p<0.01$; Table 6.1.1).

Table 6.1.1. Anthropometric characteristics of the participants (mean±SD and range).

Age Group	n	Age (years)	Height (cm)	Body mass (kg)	Body mass index
U9	183	9.2 ± 0.4 (8.2–9.7)	135.2 ± 5.4 (120.0–153.1)	30.8 ± 3.7 (23.0–41.5)	16.8 ± 1.3 (14.0–20.4)
U10	206	10.2 ± 0.3 (9.1–10.7)	140.2 ± 5.6* (124.9–161.0)	34.1 ± 4.3* (23.9–44.5)	17.3 ± 1.5 (14.1–21.0)
U11	236	11.2 ± 0.3 (10.2–11.7)	145.3 ± 6.8* (126.4–167.6)	37.6 ± 5.4* (27.1–56.5)	17.7 ± 1.6 (14.6–23.3)
U12	269	12.2 ± 0.3 (11.0–12.7)	151.6 ± 7.5* (131.6–173.2)	42.0 ± 6.5* (27.0–65.0)	18.2 ± 1.7 (14.0–23.6)
U13	248	13.2 ± 0.3 (12.2–13.7)	157.6 ± 8.7* (127.6–179.9)	46.9 ± 8.1* (30.0–70.0)	18.8 ± 1.8** (14.0–24.2)
U14	288	14.2 ± 0.3 (13.1–14.7)	166.6 ± 8.4* (145.6–195.5)	55.5 ± 9.2* (36.0–83.5)	19.9 ± 1.9* (13.9–27.5)
U15	252	15.2 ± 0.4 (14.1–15.7)	171.9 ± 8.0* (146.7–191.3)	62.2 ± 9.3* (35.5–88.7)	20.9 ± 2.0* (15.5–25.9)
U16	194	16.1 ± 0.4 (15.1–16.9)	175.9 ± 16.0* (159.4–194.5)	67.2 ± 7.8* (46.0–93.0)	21.2 ± 1.8* (17.1–28.1)
U17	136	17.2 ± 0.4 (16.3–17.9)	178.0 ± 6.7 (154.0–191.6)	70.7 ± 7.9* (40.0–86.5)	22.3 ± 1.5 (16.9–25.8)
U18	162	18.1 ± 0.4 (17.1–18.9)	179.0 ± 5.7 (166.8–193.5)	73.0 ± 7.0 (54.0–91.1)	22.7 ± 1.6 (17.5–27.0)
U19	78	19.0 ± 0.3 (18.2–19.8)	179.3 ± 5.4 (168.0–188.0)	75.5 ± 7.2 (55.0–91.0)	23.5 ± 1.8 (19.5–27.2)

Significant differences between age groups based on one-way ANOVA and post hoc Tukey analysis.
*Significantly different from previous age group $p<0.01$
**Significantly different from previous age group $p<0.05$

The mean standing height and body mass of the age group squads studied were plotted relative to British reference values (Cole et al., 1998) in Figures 6.1.1 and 6.1.2. Both standing height and body mass for this sample of elite young soccer players was found to be between the 50th and 75th centiles from the U9 to U19 age groups. Standing height ranged from the 53rd to 61st centile in the U10 and U14 age groups, respectively. Body mass ranged from the 56th to 71st centile in the U13 and U19 age groups, respectively.

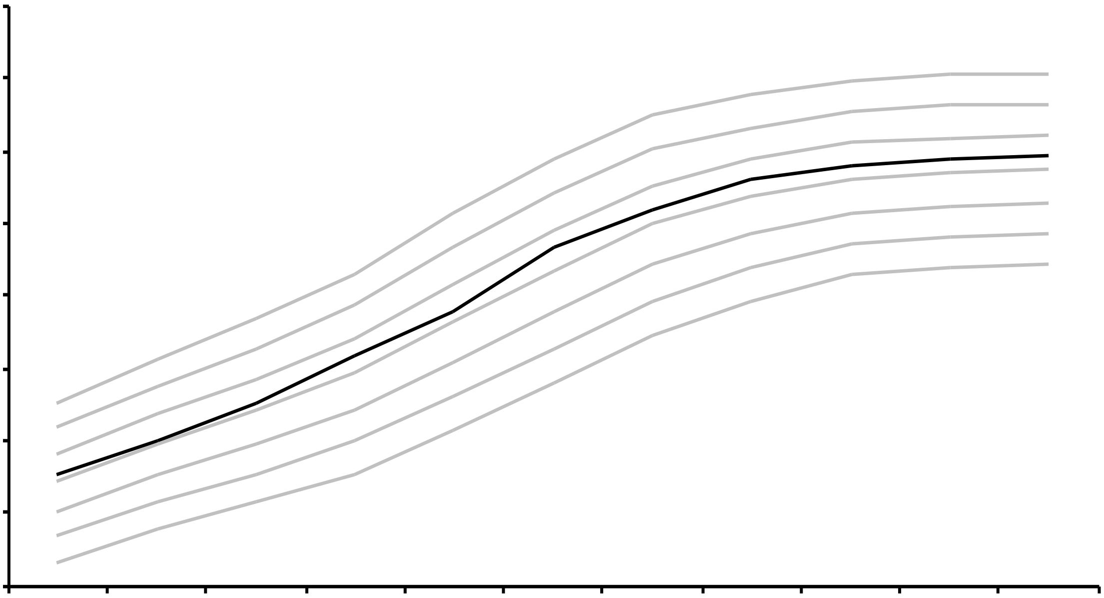


Figure 6.1.1. Standing height of English academy players (solid black line) in relation to British 1990 growth reference centiles (3rd, 10th, 25th, 50th, 75th, 90th and 97th) (Cole et al., 1998).

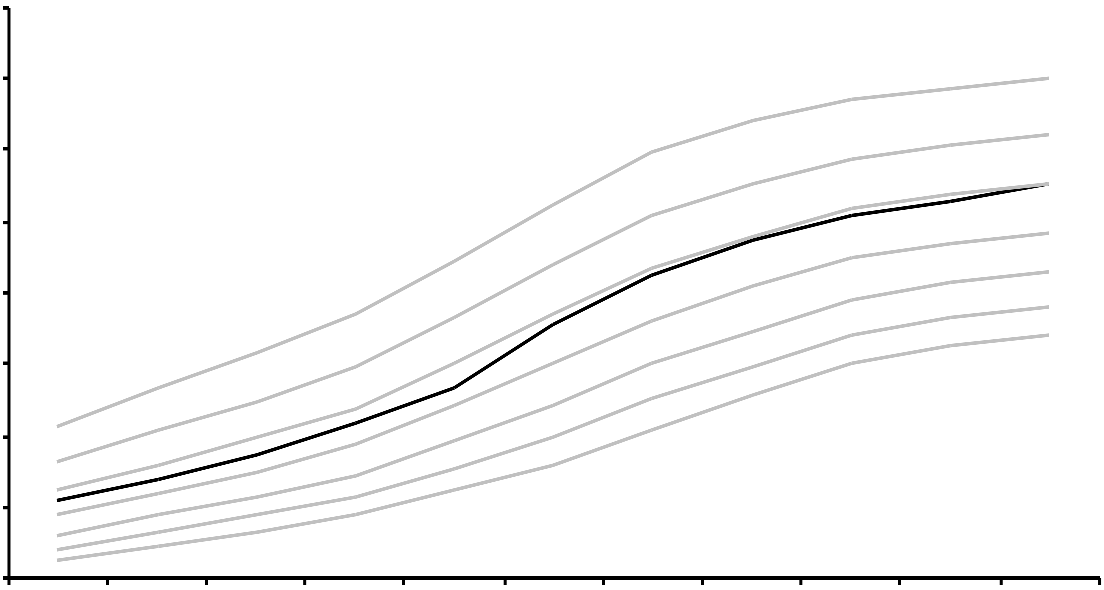


Figure 6.1.2. Body mass of English academy players (solid black line) in relation to British 1990 growth reference centiles (3rd, 10th, 25th, 50th, 75th, 90th and 97th) (Cole et al., 1998).

6.1.3.2 Physical performance characteristics

Table 6.1.2 outlines the mean jump height for each age group on the three vertical jump tests (RJ, CMJ, CMJA). The largest increase in performance between consecutive age groups in the RJ (2.8 $cm.yr^{-1}$) and CMJ (3.0 $cm.yr^{-1}$) occurred between the U13s and U14s at 13.7 years in comparison to between the U14s and U15s at 14.7 years for the CMJA (3.4 $cm.yr^{-1}$) (Table 6.1.2). No significant year-on-year improvements in jump height were noted above the U16s (RJ) and U15s (CMJ and CMJA) ($p<0.01$; Table 6.1.2).

The mean 10 and 20 m sprint and agility run times are presented for each age group in Table 6.1.2. The largest increase in performance between consecutive age groups in the 10 and 20 m sprint (-0.07 $s.yr^{-1}$ and -0.13 s $.yr^{-1}$, respectively) occurred between the U12s and U13s at 12.7 years (Table 6.1.2). The largest increase in performance between consecutive age groups in the agility test (-0.18 s. yr^{-1}) occurred earlier between the U10s and U11s at 10.7 years (Table 6.1.2). No significant year-on-year improvements in 10 and 20 m sprint above the U15s and U16s, respectively, was evident ($p<0.01$; Table 6.1.2). Significant year-on-year improvements in agility test performance were evident up to the U17s ($p<0.05$; Table 6.1.2).

The mean estimated $\dot{V}O_{2peak}$ values are presented for each age group in Table 6.1.3. The largest increase in performance between consecutive age groups in estimated $\dot{V}O_{2peak}$ (3.2 $ml.kg^{-1}.min^{-1}.yr^{-1}$) occurred between the U15s and U16s at 15.7 years. Significant year-on-year improvements in estimated VO_{2max} were evident up to the U17s ($p<0.01$; Table 6.1.3).

Table 6.1.2. Vertical jump, sprint and agility performance characteristics of players by age group category (mean±SD and range).

Age Group	RJ (cm)	CMJ (cm)	CMJA (cm)	10 m Sprint (s)	20 m Sprint (s)	Agility (s)
U9	24.5 ± 3.8 (16.0–35.0)	24.6 ± 3.9 (17.0–37.0)	27.9 ± 4.4 (17.0–41.0)	2.04 ± 0.11 (1.76–2.72)	3.70 ± 0.17 (3.19–4.21)	5.04 ± 0.30 (4.30–5.83)
U10	26.2 ± 4.0** (17.0–39.0)	26.2 ± 4.3* (17.0–40.0)	29.6 ± 4.7* (19.0–47.0)	2.00 ± 0.09* (1.79–2.31)	3.60 ± 0.17* (3.24–4.32)	4.88 ± 0.30* (4.25–6.18)
U11	27.8 ± 4.0* (17.0–42.0)	28.3 ± 4.0 (19.0–41.0)	32.2 ± 4.4 (21.0–46.0)	1.95 ± 0.09* (1.76–2.29)	3.51 ± 0.16* (3.05–4.01)	4.70 ± 0.29* (4.17–5.69)
U12	28.5 ± 4.3 (20.0–50.0)	28.8 ± 4.3* (18.0–49.0)	32.5 ± 4.9* (21.0–58.0)	1.94 ± 0.09 (1.71–2.22)	3.46 ± 0.17** (2.97–4.01)	4.68 ± 0.31 (4.03–5.83)
U13	31.1 ± 4.3* (20.0–43.0)	31.5 ± 4.6* (21.0–44.0)	35.9 ± 5.1* (24.0–51.0)	1.87 ± 0.09* (1.63–2.12)	3.33 ± 0.17* (2.92–3.87)	4.55 ± 0.27* (3.95–5.45)
U14	33.9 ± 5.0* (20.0–50.0)	34.5 ± 5.1* (22.0–50.0)	38.9 ± 5.8* (25.0–60.0)	1.82 ± 0.10* (1.57–2.11)	3.21 ± 0.18* (2.84–3.98)	4.44 ± 0.31* (3.83–5.49)
U15	36.0 ± 4.7* (24.0–50.0)	37.0 ± 5.0* (25.0–57.0)	42.3 ± 5.5* (29.0–59.0)	1.76 ± 0.09* (1.56–2.09)	3.09 ± 0.17* (2.73–3.78)	4.26 ± 0.28* (3.65–5.56)
U16	37.7 ± 5.0* (25.0–55.0)	38.7 ± 5.2 (27.0–59.0)	44.5 ± 5.7 (33.0–65.0)	1.73 ± 0.09 (1.50–2.07)	3.02 ± 0.14* (2.70–3.50)	4.17 ± 0.27** (3.59–4.99)
U17	39.0 ± 5.1 (28.0–58.0)	39.5 ± 5.5 (28.0–55.0)	45.6 ± 6.2 (31.0–73.0)	1.71 ± 0.09 (1.49–2.00)	2.97 ± 0.13 (2.66–3.47)	4.07 ± 0.26** (3.53–5.04)
U18	39.1 ± 4.5 (29.0–49.0)	40.1 ± 4.7 (29.0–51.0)	46.2 ± 5.3 (31.0–64.0)	1.70 ± 0.08 (1.50–1.90)	2.97 ± 0.11 (2.60–3.31)	4.11 ± 0.25 (3.63–5.08)
U19	39.9 ± 5.5 (25.0–55.0)	40.4 ± 5.5 (26.0–55.0)	46.5 ± 6.5 (29.0–66.0)	1.71 ± 0.08 (1.50–1.90)	2.99 ± 0.13 (2.71–3.42)	4.22 ± 0.24 (3.74–4.92)

Significant differences between age groups based on one-way ANOVA and post hoc Tukey analysis.
*Significantly different from previous age group $p<0.01$
**Significantly different from previous age group $p<0.05$

Table 6.1.3. Estimated $\dot{V}O_{2peak}$ values of players by age group category (mean±SD and range).

Age Group	N	Age (years)	$\dot{V}O_{2peak}$ (ml.kg^{-1}.min^{-1})
U9	63	9.2±0.3 (8.2–9.7)	41.2±4.9 (31.8–51.9)
U10	80	10.2±0.3 (9.1–10.7)	43.6±4.4** (33.6–52.8)
U11	81	11.2±0.3 (10.2–11.7)	45.3±4.4 (33.6–55.7)
U12	104	12.2±0.3 (11.2–12.6)	47.8±4.4* (34.3–58.2)
U13	83	13.2±0.4 (12.2–13.7)	50.2±4.2* (40.4–59.3)
U14	94	14.2±0.3 (13.5–14.7)	52.5±3.9** (43.3–61.1)
U15	73	15.2±0.4 (14.1–15.7)	54.2±3.3 (47.2–62.0)
U16	64	16.1±0.3 (15.2–16.7)	57.4±4.0* (47.7–65.6)
U17	41	17.1±0.3 (16.4–17.6)	59.0±3.6* (50.4–68.0)
U18	36	18.1±0.3 (17.3–18.7)	59.1±4.2 (49.0–68.0)
U19	8	19.2±0.3 (18.7–19.5)	57.2±3.3 (53.1–61.4)

Significant differences between age groups based on one-way ANOVA and post hoc Tukey analysis.
*Significantly different from previous age group $p<0.01$
**Significantly different from previous age group $p<0.05$

Significant correlations were found between vertical jump and sprint performance, the strongest being between CMJA and 20 m sprint (r=0.83), (Table 6.1.4).

Table 6.1.4. Anthropometric and physical performance correlations.

	Standing Height (cm)	Body mass (kg)	BMI	RJ (cm)	CMJ (cm)	CMJA (cm)	10 m Sprint (s)	20 m Sprint (s)	Agility (s)	$\dot{V}O_{2peak}$ (ml.kg^{-1}.min^{-1})
Standing Height (cm)	1.00	0.95	0.75	0.70	0.71	0.73	-0.73	-0.80	-0.65	0.73
Body mass (kg)		1.00	0.91	0.71	0.72	0.74	-0.72	-0.79	-0.63	0.69
BMI			1.00	0.62	0.62	0.64	-0.61	-0.66	-0.52	0.55
RJ (cm)				1.00	0.94	0.91	-0.76	-0.80	-0.62	0.60
CMJ (cm)					1.00	0.93	-0.77	-0.81	-0.62	0.61
CMJA (cm)						1.00	-0.79	-0.83	-0.65	0.61
10 m Sprint (s)							1.00	0.94	0.72	-0.65
20 m Sprint (s)								1.00	0.78	-0.74
Agility (s)									1.00	-0.72
VO_{2peak} (ml.kg^{-1}.min^{-1})										1.00

6.1.4 DISCUSSION

The present study is the largest study of the anthropometric and physical performance characteristics of young elite soccer players. The sample of 2,252 players from the U9 to U19 age groups compares favourably with other studies, including, Leatt, Shepard and Plyley, (1987: n=17; U16 and U18), Le Gall et al., (2002: n=328; U11 to U18), Vanderford et al., (2004: n=59; U14 to U16), Chamari et al., (2004: n=34; U18) and Le Gall et al., (2010: n=161; U14 to U16).

The observed standing height and body mass of this elite sample of young English soccer players (Table 6.1.1), is consistent with samples of elite young players from other European countries, including Croatia (Jankovic et al., 1993), Belgium (Janssens et al., 2002) and France (Le Gall et al., 2010). However, in comparison with players from other studies differences are apparent, for example, Norwegian and Danish players are taller, (Helgerud et al., 2001, Stroyer et al., 2004), Portuguese players shorter and heavier, (Malina et al., 2000), New Zealand players shorter and lighter, (Dowson et al., 2002) whilst Bulgarian players are taller and heavier (Torteva et al., 2002). In relation to such differences it has been suggested that although humans are more genetically similar than dissimilar, populations may differ in a number of genotypic and phenotypic caharacteristics, including measures of growth and maturation (Malina, Bouchard and Bar-Or, 2004).

The large range in standing height and body mass for this group of young elite players was found to be evident in all age groups, from U9 to U19 (Table 6.1.1). For example, standing height and body mass recorded for U18 players ranged from 166.8 to 193.5 cm and 54.0 to 91.5 kg, respectively. This is in line with the relative heterogeneity in body size that has been observed to be evident in groups of elite senior players (Reilly et al., 2000). The large variability in players' height and body mass will be linked with a player's suitability for different playing positions and or tactical roles within a team.

The average standing height and body mass of players in the older age groups in the current study is greater than that reported for senior English professional players in the 1970s (176.0±6.0 cm and 73.2±7.9 kg) (Reilly and Thomas, 1977) and 1980s (1.77±0.2 m and 74.0±1.6 kg) (Reilly, 1990). This observation adds some support to the suggestion that the size of players at the elite level in terms of standing height and body mass is increasing (Shepard, 1999). However, given evidence of a global trend in increasing body size (Garn, 1987) it is likely that soccer players are also increasing in size (Nevill, Holder and Watts, 2009). It has also been observed that elite athletes from other sports where size is an advantage have become larger in recent times (Norton and Olds, 2001). When compared to British 1990 growth reference centiles (Cole et al., 1998) the players standing height and body mass is above the 50th centile from the U9 to U19 age groups (Figures 2 and 3). This finding supports the argument that increased selection opportunities in soccer tend to favour older and physically taller boys (Brewer, Balsom and Davis, 1995). Providing further explanation to this argument a number of reasons have been suggested as to why taller more linear players are likely to be more successful, including, being more successful at heading the ball, being more likely to be successful when tackling opponents given their diproportionally longer legs and being more likely to perform better when running over longer distances (Nevill, Holder and Watts, 2009).

The mean age at PHV in the present study was 13.7 years. This is earlier than estimates of PHV for 32 Welsh (Bell, 1993) and 8 Danish (Froberg et al, 1991) youth soccer players of 14.2 $\pm$ 0.9 years, and is just outside the range of estimated ages at PHV for samples of European boys (13.8 – 14.2 years; Malina et al, 2004). One may have expected this slightly earlier onset of PHV in the elite players studied based on suggestions of a selection bias related to advanced maturity status, where taller and heavier players have an increased likelihood of selection, (Brewer, Balsom and Davis, 1995; Helsen et al., 2000). The present finding along with the earlier estimated mean age at PHV reported for 33 Flemish players of 13.8 $\pm$ 0.8 years by Philippaerts and colleagues (2006) would support this view of a selection bias. The PHV of 9.0 $cm.yr^{-1}$ for this group of elite players is within the range of 8.2 to 10.3 $cm.yr^{-1}$ reported for European boys (Malina et al, 2004). However, this figure is less than the estimated PHV of 9.7 $cm.yr^{-1}$ reported for Flemish players (Philippaerts et al, 2006).

In the present study the majority of the largest increases in performance between consecutive age groups occurred either just prior to (10 and 20 m sprint) or coincident with (RJ; CMJ) the timing of PHV. These findings are comparable with similar performance items studied in Flemish youth soccer players who were reported to reach a mean peak performance velocity concurrent with PHV (Philippaerts et al., 2006). However, these findings contrast with observations of elite Belgian players where the largest improvements in sprint (5 m, 10 m and 20 m) and vertical jump (CMJ and CMJA) performance occurred somewhat later, between 15 and 17 years (Cedric et al., 2007). Studies of the general population of adolescent males suggest that maximal gains in muscular strength and power generally occur after PHV (Malina et al, 2004). It has been suggested that this is related to the adolescent spurt in muscle mass that follows PHV (Malina et al., 2004). The present data for elite young soccer players indicated that significant year on year improvements in vertical jump and sprint performance were only evident for 12 to 24 months after PHV (Table 2). Agility and endurance performance displayed significant improvements up to 36 months after PHV (Table 6.1.2). Such performance gains after PHV have been attributed to continued growth and the positive effects of systematic sports training (Philippaerts et al., 2006).

A notable trend in the performance data is for no significant improvements in vertical jump and sprint speed to be evident 12 to 24 months after PHV. This trend exists despite the switch from part-time training (U12 to U16: not less than 5 hours per week) to full-time training (U17 to U21: not less than 12 hours per week) (Wilkinson, 1997). Based on these findings one may suggest that the majority of the physical performance improvements in terms of vertical jump and sprint speed observed in this population of young players is the product of growth as opposed to training adaptations. Conversely, agility and endurance performance was still found to significantly improve 36 months after PHV. This may highlight the fact that the aspects of agility and endurance are physical qualities which are more trainable than other physical characteristics such as speed and power. Indeed, it has been suggested that approximately 30% of $\dot{V}O_{2peak}$ can be accounted for by training itself (Baxter-Jones and Maffulli, 2003). Also, because of the perceived importance of agility in soccer performance (Reilly et al., 2000) it may be that more training time is invested in improving players agility as opposed to straight line sprint speed and/or vertical jump height. For example, it was recently suggested that soccer specific running and agility drills may be an effective alternative to basic strength and conditioning programmes for developing the physical performance of soccer players (Julien et al., 2008). However, strength has been shown to be closely correlated with vertical jump and sprint speed (Hrysomallis et al., 2002) and therefore the requirement for appropriate strength work would appear beneficial. It may be the case that such strength training is not being accommodated in the training programmes of these elite young players. Furthermore, it is of interest to note that when Young and colleagues (2001) examined the specificity of the training response to straight sprint or agility training over a six week period it was found that a training method specific to one speed quality produced limited transfer to the other.

It has recently been suggested that a vertical jump (CMJA) height of close to 60 cm would be expected from an elite player (Wisloff et al., 1998). Although the mean values recorded for the older players in the present study are somewhat less than this, the range of values recorded indicates that some English academy players are capable of jumping in excess of 60 cm (Table 6.1.2). Le Gall and colleagues (2010) used a vertical jump methodology similar to that employed in the present, with young elite French players performing three CMJA on a jump mat with data from the best effort being recorded. The CMJA heights reported for the young elite French players were higher (~5cm) than those reported here for their English counterparts (le Gall et al., 2010). It should be noted that the French players were all in attendance at a national academy as opposed to the club academy players in the present study and therefore may represent a more select group. The vertical jump height of young Scottish and Canadian players would also appear higher, although only 11 and 17 players respectively, were involved in these studies (McMillan et al., 2005; Leatt, Shepard and Plyley, 1987).

The 10 m and 20 m sprint times recorded for the English academy players suggest that they are comparatively quick, with the sprint times reported for elite French players being slower (~0.1 s) (le Gall et al., 2010). Similarly, sprint times reported for elite junior players in Scotland (McMillan et al., 2005), Tunisia (Chamari et al., 2004) and Norway (Helgerud et al., 2001) are all slower in comparison to the sprint times reported in the present study. However, it is difficult to make accurate assessments of such comparisons given potential differences in the testing protocols employed in respective studies. For example, the nature of the surface used to assess sprint speed can have a significant effect on results and therefore make any comparison problematic.

The estimated values obtained for $\dot{V}O_{2peak}$ in this study are lower than those found for elite junior players in Norway, 64.3 $ml.kg^{-1}.min^{-1}$ (Helgerud et al., 2001), Denmark (63.7 $ml.kg^{-1}.min^{-1}$) (Stroyer et al., 2004) and Scotland (69.8 $ml.kg^{-1}.min^{-1}$) (McMillan et al., 2005). This may be partly explained by the different methods employed to determine $\dot{V}O_{2peak}$ in the respective studies. For example, McMillan and colleagues (2005) used a portable metabolic test system to measure $\dot{V}O_{2peak}$ during an incremental treadmill test where the inclination of the treadmill was kept at 5.5% with the velocity being increased by 1 $km.h^{-1}$ every minute to a level that brought the subject to exhaustion after approximately 5-6 minutes. Therefore, it should be taken into consideration that the MSFT which was used to estimate $\dot{V}O_{2peak}$ in the current study has a tendency to underestimate values of $\dot{V}O_{2peak}$ (Sproule et al., 1993). However, despite this tendency to underestimate values of $\dot{V}O_{2peak}$ the fact that the

MSFT was conducted in the field would appear to enhance the specificity and validity of the results. For example, unlike treadmill based tests of $\dot{V}O_{2peak}$ players performed the MSFT in their normal playing footware on the surface which they regularly trained. Furthermore, the nature of the MSFT where players are required to turn every 20m is more closely related to the type of movements that players perform during a games and training. Based on these facts it may be argued that players are more likely to perform maximally on the MSFT because of their familiarity with its protocol and the environment in which the test was performed.

In conclusion, the key finding of the present study is that the greatest changes in anthropometric and physical performance characteristics in young, elite soccer players would appear to occur between the early to mid-teenage years.

6.1.4.1 Practical applications

The data presented allows coaches to be aware of the timing and magnitude of the anthropometric and physical performance changes that are taking place in elite child and adolescent soccer players. This will facilitate the adoption of appropriate methods of training in squads of young, elite soccer players. The normative data and performance standards that have been established in this study for elite young players will provide coaches and sports scientists with an objective tool to support the process of talent identification in elite soccer.

6.2 A COMPARISON OF ANTHROPOMETRIC AND PHYSICAL PERFORMANCE CHARACTERISTICS AMONG PLAYING POSITIONS IN ELITE CHILD AND ADOLESCENT SOCCER PLAYERS.

6.2.1 INTRODUCTION

Studies of senior professional players' have shown that the physiological demands of soccer vary in relation to the work-rates associated with different positional roles (Reilly, Bangsbo and Franks, 2000). In a number of studies players have been classified into one of four positional groups, comprising, goalkeepers, defenders, midfielders and forwards (Wisloff, Helgerud and Hoff, 1998; Malina et al., 2000; Rienzi et al., 2000). Other researchers have based their analysis on five positional groups, classifying defenders as either fullbacks or centrebacks (Davis, Brewer and Atkin, 1992; Di Salvo and Pigozzi, 1998).

For senior professional players it has been suggested that aerobic requirements are highest in midfield players who have been reported to cover the greatest distance during a game (Ekblom, 1986; Rienzi et al., 2000). It has also been noted that fullbacks and forwards sprint significantly further than centrebacks and midfielders throughout the course of a game (Mohr, Krustrup and Bangsbo, 2003). Such differences have been reflected in the physiological profiles of elite senior players in accordance with their playing positions (Reilly, 1994). For example, midfielders and goalkeepers have been shown to display the highest and lowest values of maximal oxygen uptake ($\dot{V}O_{2max}$), respectively (Davis, Brewer and Atkin, 1992; Wisloff, Helgerud and Hoff, 1998). Whereas other researchers have suggested the forward players to be the fastest in terms of sprint speed (Sena et al., 1997; Gil et al., 2007).

Related to these physical performance differences some studies have also highlighted anthropometric differences to exist between respective playing positions for senior professional players (Reilly, 1994; Bangsbo and Michalsik, 2002). It has been suggested that taller players have an advantage in certain playing positions, including, goalkeeper, centreback and central forward and as a consequence are selected for these roles within a team (Reilly, Bangsbo and Franks, 2000). However, there is a sparsity of studies examining the anthropometric and physical performance differences between young elite players who play in different positions (Gil et al., 2007) and furthermore, many of the studies involving younger players are limited to a small selection of age groups (Franks et al., 1999; Malina et al., 2000; Neto et al., 2003). Therefore, the aim of the present study was to compare the anthropometric and physical performance characteristics of elite young soccer players in relation to specific playing positions throughout a broad range of age groups. The hypothesis to be tested was that the anthropometric and physical performance characteristics of elite young players varies in relation to playing position.

6.2.2 METHODS

6.2.2.1 Participants

Participant information is provided in section 3.3.4.

6.2.2.2 Procedures

A detailed description of the procedures and physical performance testing protocol can be found in sections 3.3 and 3.4.

6.2.2.3 Statistical analysis

Data were analysed using SPSS (Version 16.0, Chicago, Illinois, USA). Descriptive statistics were calculated. One-way analysis of variance (ANOVA) was used to investigate differences in anthropometric and physical performance variables between the different playing positions. When a significant playing position effect was found a Tukey post hoc test was used to test differences among means. Standing height and body mass measurements were compared against British 1990 growth reference centiles (Cole et al., 1998) using the LMS method (Cole and Green, 1992). Statistical significance was accepted at the 95% confidence level ($p<0.05$). Values are reported as mean (±SD).

6.2.3 RESULTS

6.2.3.1 Positional characteristics

Midfielders and goalkeepers comprised the largest and smallest positional groups within the English Academy players studied, respectively (Table 6.2.1). The relative number of multi-positional players decreased with an increase in age group (Table 6.2.1).

Table 6.2.1. Distribution of players in relation to playing position and age group.

Age Group	Playing Position (n)						Total (n)
	Goalkeeper	Full Back	Centreback	Midfield	Forward	Multi-positional	
U9	11	12	31	62	34	33	183
U10	15	24	24	75	30	38	206
U11	20	27	27	72	50	40	236
U12	31	30	39	93	50	26	269
U13	9	47	39	90	51	12	248
U14	24	36	41	121	56	10	288
U15	17	40	40	87	55	13	252
U16	18	31	26	59	48	12	194
U17	14	22	20	44	30	6	136
U18	12	29	25	45	45	6	162
U19	8	8	13	27	19	3	78
Total (n)	179	306	325	775	468	199	
%	7.9	13.6	14.4	34.4	20.8	8.8	

6.2.3.2 Anthropometric characteristics

In the younger age groups (U9s and U10s) there were no differences in standing height or body mass between players in different playing positions (N.S.; Table 6.2.2). In the U11 to U19 age groups significant differences were detected in standing height and body mass (Table 6.2.2). Goalkeepers and centerbacks were taller ($p<0.05$) in relation to other positions, in particular fullbacks ($p<0.05$) and midfielders ($p<0.05$; Table 6.2.2). Similarly, goalkeepers and centrebacks were heavier ($p<0.05$) in relation to other positions, especially when compared to midfielders ($p<0.05$; Table 6.2.2).

When standing height was analysed in relation to British growth reference centiles (Cole et al., 1998) goalkeepers and centrebacks were found to be above the 75th centile in the majority of age groups (Figure 6.2.1). Contrary to this, fullbacks and midfielders were below the 50th centile in a number of age groups (Figure 6.2.1).

Table 6.2.2. Anthropometric characteristics of players in relation to age group and playing position (mean±SD and range).

Age Group (years)	Standing Height (cm)					
	Goalkeeper	Fullback	Centreback	Midfielder	Forward	Multipositional
U9	137.3±6.5 (130.5-153.1)	136.7±3.5 (131.6-144.0)	136.1±5.3 (127.6-148.0)	135.3±5.3 (12.0-148.5)	134.7±5.7 (122.1-147.9)	133.7±5.4 (123.0-145.0)
U10	142.3±6.3 (131.6-152.9)	139.2±5.1 (128.9-147.9)	141.2±5.0 (132.5-153.2)	140.2±6.0 (124.9-161.0)	140.2±5.6 (128.0-150.0)	139.3±5.1 (128.0-148.1)
U11	150.0±9.0 (134.0-167.6)	143.6±5.8[a] (134.2-151.7)	148.3±7.1 (136.0-165.4)	143.7±6.7[a,b] (126.4-167.1)	145.8±6.3 (131.3-160.0)	144.1±5.7[a] (128.0-155.4)
U12	155.7±6.6 (143.0-167.8)	151.1±7.0 (133.0-167.5)	153.9±7.0 (141.2-167.1)	150.6±7.7[a] (131.6-173.2)	150.4±7.4[a] (136.3-166.2)	149.2±7.1[a] (136.1-164.5)
U13	165.3±6.2 (156.0-177.1)	156.3±6.9[a,b] (142.6-176.6)	161.5±9.6 (141.7-177.8)	154.7±7.8[a,b,c] (127.6-178.1)	159.7±9.4 (141.7-179.3)	157.2±8.4 (145.6-170.4)
U14	172.0±7.3 (153.6-184.4)	162.8±7.4[a,b,c] (147.5-176.0)	170.8±9.0 (147.0-191.0)	164.0±7.9[a,b,c] (145.6-190.0)	168.9±7.6 (154.0-195.5)	167.9±6.4 (159.7-177.8)
U15	178.9±5.2 (172.6-191.3)	170.9±6.6[a,b] (151.6-183.6)	177.1±7.1 (152.1-189.0)	168.9±8.1[a,b] (146.7-189.0)	170.9±6.8[a,b] (153.1-185.5)	174.3±8.3 (161.6-188.1)
U16	179.5±5.6 (173.2-191.1)	173.2±4.4[a,b] (161.2-180.6)	182.5±4.5 (171.7-194.5)	174.3±4.9[a,b] (161.3-187.6)	175.6±6.3[b] (159.4-187.0)	173.0±5.2[a,b] (163.0-184.1)
U17	185.9±4.2 (174.5-191.6)	174.4±5.5[a,b] (163.5-185.0)	184.0±3.7 (175.9-190.4)	175.5±6.4[a,b] (154.0-184.0)	177.0±5.6[a,b] (163.4-187.3)	176.3±1.4[a,b] (175.0-178.5)
U18	183.9±3.9 (178.5-191.6)	177.2±5.7[a,b] (168.8-191.1)	183.7±4.2 (170.5-189.5)	177.8±5.2[a,b] (166.8-193.5)	178.1±5.6[a,b] (166.8-192.2)	175.1±4.9[a,b] (168.6-181.9)
U19	183.6±3.3 (177.5-188.0)	177.3±6.0[b] (169.6-183.7)	184.2±2.0 (181.1-188.0)	177.3±5.3[a,b] (168.0-186.5)	177.3±5.0[a,b] (168.5-185.6)	181.6±4.2 (178.8-186.4)
Age Group (years)	Body mass (kg)					
	Goalkeeper	Fullback	Centreback	Midfielder	Forward	Multipositional
U9	31.2±3.3 (25.0-36.9)	31.5±3.8 (25.0-37.1)	31.1±4.1 (23.0-40.0)	30.4±3.4 (23.0-38.0)	31.1±4.1 (24.0-41.5)	30.6±3.6 (24.0-38.0)
U10	35.4±4.9 (29.0-44.5)	33.5±2.8 (28.0-39.2)	34.5±4.1 (26.7-43.0)	34.5±4.4 (23.9-44.0)	33.9±4.8 (27.2-42.8)	33.2±4.2 (26.1-42.5)
U11	40.8±6.9 (30.6-56.0)	36.8±5.7 (27.5-53.5)	38.9±6.4 (30.0-52.5)	36.9±4.9[a] (27.1-56.5)	38.2±4.9 (28.5-55.0)	36.1±4.7[a] (28.0-45.6)
U12	45.4±5.5 (34.6-63.0)	41.3±7.0 (27.0-65.0)	43.5±5.7 (31.0-55.0)	41.5±6.8[a] (28.0-58.5)	41.4±6.4 (29.5-60.0)	39.1±6.0[a] (30.0-55.0)
U13	54.3±10.0 (38.4-70.0)	45.4±6.9[a] (35.0-66.6)	49.4±8.2 (30.0-68.5)	44.4±6.5[a,b,c] (31.0-64.5)	49.7±9.2 (34.8-67.0)	46.1±8.4 (35.0-63.2)
U14	60.6±8.7 (44.3-82.0)	51.5±7.9[a,b,c] (38.5-69.0)	58.4±9.7 (40.0-83.5)	53.5±8.8[a,b,c] (36.0-82.8)	57.6±8.8 (43.9-80.0)	57.8±6.8 (50.9-68.3)
U15	69.7±6.6 (60.0-88.7)	61.6±7.0[a] (41.0-74.2)	66.7±8.3 (39.8-80.0)	58.7±9.7[a,b] (35.5-82.0)	62.5±9.0[a] (40.0-78.6)	63.8±9.0 (44.0-77.7)
U16	71.3±9.5 (58.0-93.0)	64.0±6.6[a,b] (46.5-74.5)	73.1±7.6 (62.0-93.0)	65.0±6.0[a,b] (53.5-83.0)	67.6±8.3[b] (46.0-87.0)	66.0±6.1 (56.4-74.9)
U17	76.8±5.3 (67.2-84.5)	67.2±7.2[a,b] (53.0-80.5)	77.9±5.4 (64.5-86.5)	67.5±7.7[a,b] (40.0-81.0)	70.6±6.7[b] (55.0-82.0)	69.6±6.3 (59.0-78.5)
U18	80.3±4.0 (74.0-86.5)	70.5±5.3[a,b] (63.0-86.5)	78.8±7.3 (54.5-91.5)	70.6±6.3[a,b] (54.0-81.0)	72.5±6.2[a,b] (62.0-88.0)	67.5±2.7[a,b] (63.2-70.0)
U19	82.6±5.3 (72.0-88.0)	71.7±4.3[a] (66.0-77.0)	78.4±6.6 (67.0-91.0)	74.3±6.6[a] (55.0-88.6)	74.1±8.3[a] (59.0-87.0)	73.8±6.5 (66.5-79.0)

Significant differences between playing positions within each age group based on one-way ANOVA and post hoc Tukey analysis within age groups.
[a]Significantly different from goalkeepers $p<0.05$
[b]Significantly different from centrebacks $p<0.05$
[c]Significantly different from forwards $p<0.05$

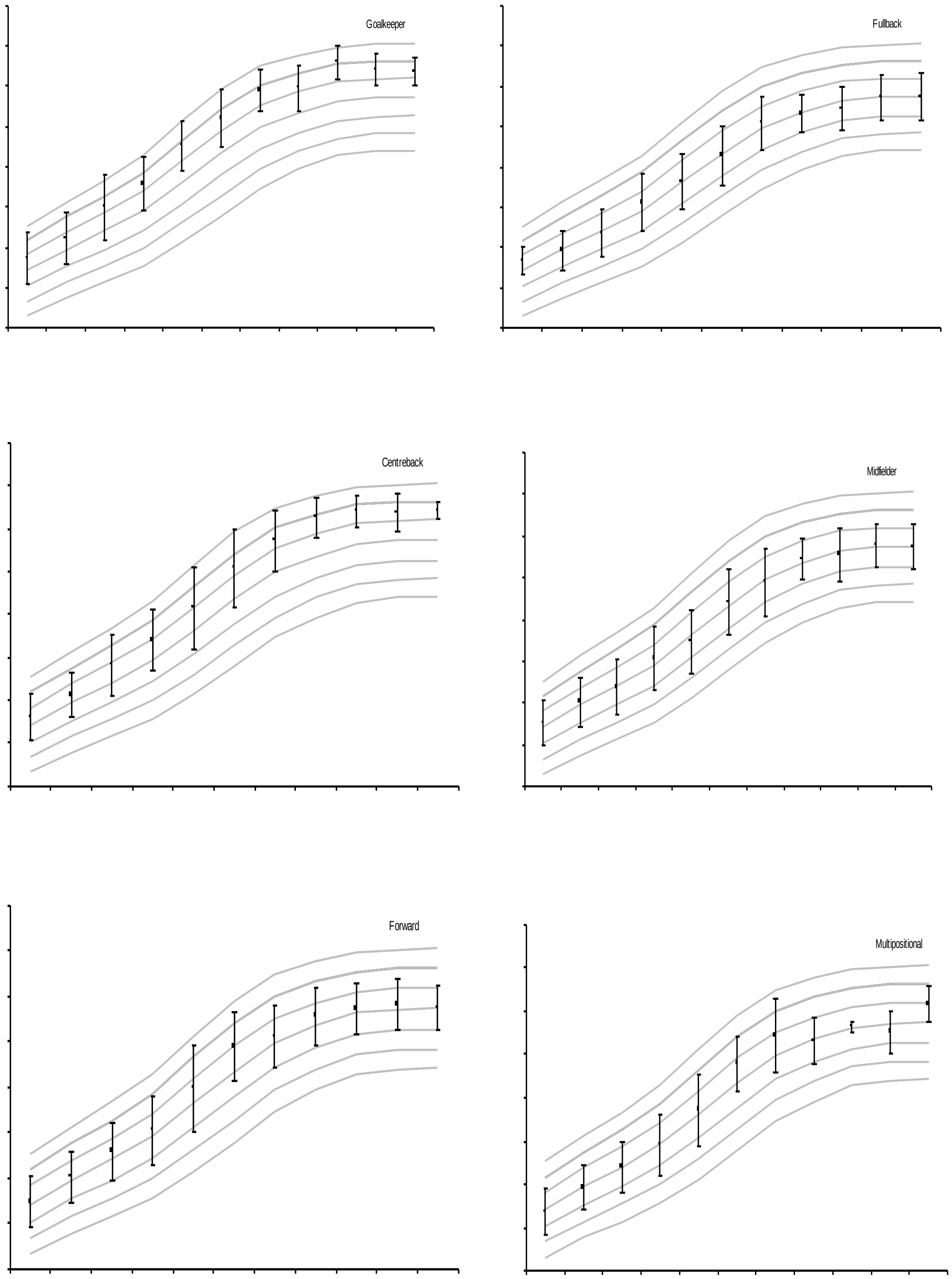


Figure 6.2.1. Standing height of players by playing position (mean±SD) in relation to British 1990 growth reference centiles (3rd, 10th, 25th, 50th, 75th, 90th and 97th) (Cole et al., 1998).

6.2.3.3 Physical performance characteristics

Excluding the forward players, vertical jump performance (RJ; CMJ; CMJA) was generally comparable across all playing positions (Table 6.2.3). The forwards were found to jump significantly higher ($p<0.05$), particularly in the U13 and U16 age groups in comparison to the fullbacks ($p<0.05$) and midfielders ($p<0.05$; Table 6.2.3).

The main significant difference in sprint (10 m and 20 m) and agility performance was for goalkeepers to be slower in comparison to outfield players ($p<0.05$; Table 6.2.4). The only significant difference amongst outfield players in 10 m sprint performance was between forwards and fullbacks in the U13 age group, with the forwards being faster ($p<0.05$; Table 6.2.4). There were differences in 20 m speed between playing positions for U13, U16 and U18 players ($p<0.05$; Table 6.2.4). The U13 forwards were faster than the U13 midfielders and U13 fullbacks ($p<0.05$), U16 forwards were faster than U16 midfielders ($p<0.05$) and U18 fullbacks were faster than U18 midfielders ($p<0.05$; Table 6.2.4).

No significant differences were observed between outfield players in terms of estimated $\dot{V}O_{2peak}$ (N.S.; Table 6.2.5). The estimated $\dot{V}O_{2peak}$ values of the goalkeepers were significantly lower in comparison to some outfield positions in the U12, U13 and U15 age groups ($p<0.05$; Table 6.2.5).

Table 6.2.3. Vertical jump performance of players in relation to age group and playing position (mean±SD).

Age Group (years)	RJ (cm)					
	Goalkeeper	Fullback	Centreback	Midfielder	Forward	Multipositional
U9	23.5±4.4	22.9±3.3	25.5±3.3	24.7±3.9	24.8±4.4	23.8±3.3
U10	26.1±3.6	25.9±3.7	26.8±3.9	25.9±4.4	27.6±3.5	25.4±3.9
U11	27.2±3.9	28.5±3.9	27.4±4.1	27.8±4.0	28.6±4.7	27.8±3.1
U12	27.1±3.5	28.5±3.3	28.3±3.4	28.7±4.3	29.8±5.5	26.9±4.4
U13	32.6±2.7	29.8±3.9[c]	30.6±4.1[c]	30.3±4.1[c]	33.2±4.5	32.8±5.1
U14	33.5±4.7	32.9±4.1	34.8±3.9	33.7±5.2	34.4±6.0	33.7±5.4
U15	35.4±4.5	35.6±3.9	36.6±4.0	35.0±4.7	37.2±5.4	37.3±5.1
U16	36.6±4.6	37.8±5.4	38.0±4.4	36.5±4.6[c]	39.5±5.5	37.4±4.5
U17	38.2±3.3	38.2±3.8	39.8±5.7	38.6±5.4	39.1±4.8	44.5±7.9
U18	38.8±4.1	40.1±3.7	38.9±4.3	37.9±4.6	39.2±4.7	43.5±3.3[d]
U19	42.5±5.8	38.9±5.4	40.3±3.9	39.0±6.4	40.3±5.5	40.3±2.5
Age Group (years)	CMJ (cm)					
	Goalkeeper	Fullback	Centreback	Midfielder	Forward	Multipositional
U9	22.5±2.2	22.5±2.3	25.7±3.2	25.1±3.8	24.9±5.4	24.0±3.4
U10	25.8±4.1	25.6±4.4	26.9±3.2	26.1±4.7	27.0±4.4	25.6±4.1
U11	27.7±3.5	28.8±3.9	27.4±4.4	28.4±3.8	28.8±4.7	28.0±3.3
U12	26.9±3.0[c]	28.8±4.1	28.6±3.4	29.0±4.2	30.4±5.3	27.5±4.7
U13	33.2±3.3	29.9±4.4[c]	31.2±3.7	31.2±4.2[c]	33.6±5.3	31.4±5.8
U14	33.4±4.9	34.1±4.8	35.4±4.3	33.9±5.1	35.5±5.6	35.9±4.6
U15	36.4±4.9	36.5±4.0	37.6±4.2	36.0±5.0	38.3±5.7	38.3±5.6
U16	37.2±5.7	38.9±5.2	38.8±4.7	37.6±5.1[c]	40.6±5.3	37.2±4.3
U17	37.8±3.2	38.7±4.7	40.2±5.9	39.2±5.6	40.0±6.1	43.5±7.2
U18	40.3±3.9	41.1±4.0	40.2±4.8	39.0±5.1	40.1±4.7	44.0±4.8
U19	43.6±4.7	39.3±5.4	40.8±4.6	39.4±5.8	40.5±6.3	40.7±0.6
Age Group (years)	CMJA (cm)					
	Goalkeeper	Fullback	Centreback	Midfielder	Forward	Multipositional
U9	25.0±2.4	25.8±3.2	29.6±3.7[a]	28.6±4.0	27.7±5.6	26.8±4.3
U10	29.1±4.3	28.8±4.4	31.3±4.5	28.9±5.3	30.6±4.2	29.6±4.3
U11	32.0±3.8	31.7±4.3	31.3±4.5	32.4±3.9	33.0±5.4	32.1±4.0
U12	31.4±3.5	32.7±4.5	32.3±4.2	32.5±4.7	34.1±6.4	31.0±5.0
U13	37.0±3.7	34.0±4.5[c]	35.5±4.6	35.5±5.0[c]	38.3±5.3	36.1±5.8
U14	37.7±5.5	37.9±4.8	39.9±5.2	38.7±6.0	39.5±6.4	40.6±6.1
U15	41.6±6.0	41.8±4.4	42.6±4.6	41.5±5.4	43.6±6.3	43.5±6.6
U16	42.4±5.8	45.5±6.2	44.1±4.6	43.4±4.8[c]	46.7±6.6	43.5±5.3
U17	44.1±3.9	44.5±3.6	46.5±6.9	45.1±6.8	46.3±6.8	50.0±5.9
U18	45.9±5.5	46.9±4.2	46.8±4.8	44.6±5.1	46.5±5.6	50.3±8.0
U19	50.4±7.0	44.1±4.6	47.1±5.8	45.6±7.0	46.6±7.1	46.7±3.5

Significant differences between playing positions within each age group based on one-way ANOVA and post hoc Tukey analysis within age groups.
[a]Significantly different from goalkeepers $p<0.05$
[b]Significantly different from centrebacks $p<0.05$
[c]Significantly different from forwards $p<0.05$
[d]Significantly different from midfielders $p<0.05$

Table 6.2.4. Sprint and agility performance of players in relation to age group and playing position (mean±SD).

Age Group (years)	10 m Sprint (s)					
	Goalkeeper	Fullback	Centreback	Midfielder	Forward	Multipositional
U9	2.15±0.10	2.09±0.08	2.02±0.11[a]	2.03±0.12[a]	2.03±0.10[a]	2.03±0.09[a]
U10	2.04±0.08	1.99±0.09	1.98±0.09	2.00±0.09	2.01±0.08	2.01±0.11
U11	2.03±0.10	1.92±0.07[a]	1.96±0.10	1.97±0.09[a]	1.93±0.08[a]	1.94±0.08[a]
U12	1.99±0.09	1.95±0.11	1.94±0.08	1.93±0.09[a]	1.91±0.10[a]	1.92±0.06[a]
U13	1.87±0.07	1.91±0.09[c]	1.85±0.08	1.88±0.10	1.83±0.08	1.89±0.08
U14	1.87±0.11	1.84±0.10	1.82±0.10	1.82±0.09	1.79±0.09[a]	1.82±0.09
U15	1.81±0.09	1.75±0.09	1.75±0.09	1.77±0.09	1.74±0.09[a]	1.74±0.09
U16	1.77±0.09	1.73±0.09	1.73±0.08	1.74±0.09	1.70±0.07[a]	1.77±0.13
U17	1.76±0.12	1.69±0.07	1.71±0.10	1.71±0.10	1.71±0.07	1.63±0.08[a]
U18	1.72±0.06	1.68±0.06	1.71±0.07	1.72±0.08	1.70±0.09	1.69±0.08
U19	1.72±0.06	1.71±0.12	1.68±0.09	1.73±0.06	1.72±0.09	1.72±0.13
Age Group (years)	20 m Sprint (s)					
	Goalkeeper	Fullback	Centreback	Midfielder	Forward	Multipositional
U9	3.94±0.16	3.77±0.11	3.66±0.14[a]	3.68±0.16[a]	3.69±0.19[a]	3.68±0.16[a]
U10	3.72±0.17	3.58±0.17	3.55±0.13[a]	3.59±0.16	3.59±0.16	3.62±0.19
U11	3.67±0.17	3.46±0.12[a]	3.52±0.17[a]	3.54±0.15[a]	3.46±0.14[a]	3.50±0.15[a]
U12	3.58±0.15	3.50±0.18	3.45±0.14[a]	3.45±0.16[a]	3.42±0.20[a]	3.44±0.12[a]
U13	3.30±0.11	3.39±0.16[c]	3.31±0.16	3.35±0.18[c]	3.26±0.16	3.41±0.17
U14	3.30±0.24	3.24±0.16	3.19±0.16	3.23±0.18	3.16±0.18[a]	3.21±0.15
U15	3.17±0.13	3.09±0.15	3.08±0.20	3.12±0.18	3.04±0.15	3.08±0.13
U16	3.11±0.15	3.01±0.14	3.01±0.11	3.04±0.14[c]	2.96±0.12[a]	3.08±0.16
U17	3.08±0.16	2.95±0.11[a]	2.96±0.15	2.98±0.14	2.96±0.10[a]	2.86±0.11
U18	3.04±0.12	2.92±0.09[a,d]	2.98±0.10	3.01±0.12	2.94±0.12	2.93±0.14
U19	3.00±0.09	2.96±0.13	2.95±0.11	3.01±0.13	3.01±0.14	2.98±0.20
Age Group (years)	Agility (s)					
	Goalkeeper	Fullback	Centreback	Midfielder	Forward	Multipositional
U9	5.30±0.22	5.17±0.24	5.01±0.31	5.03±0.27	5.05±0.32	4.92±0.32[a]
U10	5.00±0.33	4.82±0.21	4.92±0.26	4.93±0.29	4.81±0.32	4.81±0.35
U11	4.91±0.28	4.70±0.28	4.75±0.29	4.74±0.30	4.60±0.24[a]	4.64±0.28[a]
U12	4.84±0.30	4.75±0.29	4.59±0.29[a]	4.66±0.29	4.65±0.32	4.67±0.38
U13	4.47±0.25	4.60±0.26	4.54±0.30	4.54±0.25	4.51±0.29	4.65±0.38
U14	4.53±0.35	4.39±0.27	4.41±0.28	4.47±0.33	4.39±0.33	4.37±0.20
U15	4.29±0.23	4.25±0.28	4.27±0.34	4.27±0.26	4.24±0.29	4.31±0.25
U16	4.37±0.22	4.14±0.27[a]	4.09±0.25[a]	4.22±0.27	4.13±0.25[a]	4.09±0.23[a]
U17	4.30±0.34	4.04±0.22	4.06±0.15[a]	4.05±0.29[a]	4.03±0.23[a]	3.94±0.14[a]
U18	4.29±0.32	4.09±0.23	4.14±0.23	4.09±0.22	4.06±0.26	4.14±0.29
U19	4.31±0.13	4.06±0.15	4.16±0.28	4.28±0.21	4.22±0.26	4.14±0.42

Significant differences between playing positions within each age group based on one-way ANOVA and post hoc Tukey analysis within age groups.
[a]Significantly different from goalkeepers $p<0.05$
[c]Significantly different from forwards $p<0.05$
[d]Significantly different from midfielders $p<0.05$

Table 6.2.5. Estimated $\dot{V}O_{2peak}$ of players in relation to age group and playing position (mean±SD).

Age Group (years)	Estimated $\dot{V}O_{2peak}$ (ml.kg^{-1}.min^{-1})					
	Goalkeeper	Fullback	Centreback	Midfielder	Forward	Multipositional
U9	36.4±2.5	43.0±2.1	42.8±4.9	40.0±4.8	40.8±5.2	43.4±5.4
U10	45.1±4.2	43.0±3.7	43.5±4.3	44.3±4.5	44.1±4.4	42.7±4.6
U11	40.8±3.9	44.8±5.2	47.7±4.2	45.7±4.2	44.7±4.2	45.4±4.3
U12	43.5±3.2	47.5±2.4	49.1±3.7[a]	48.6±4.5[a]	47.7±5.2	46.4±4.4
U13	44.9±4.2	50.1±3.4	50.6±5.2	50.6±4.2	49.4±3.5	53.1±3.7[a]
U14	49.5±5.6	52.5±4.1	52.7±3.2	52.8±3.8	52.5±3.5	54.7±4.2
U15	50.3±3.0	54.1±3.1	56.2±2.8[a]	54.7±3.2[a]	53.6±2.4	55.1±4.1
U16	54.0±5.0	56.7±3.9	57.6±3.0	58.2±3.6	56.9±4.3	58.5±5.6
U17	N/A	N/A	N/A	N/A	N/A	N/A
U18	N/A	N/A	N/A	N/A	N/A	N/A
U19	N/A	N/A	N/A	N/A	N/A	N/A

Significant differences between playing positions within each age group based on a one-way ANOVA and post hoc Tukey analysis within age groups.
[a]Significantly different from goalkeepers $p<0.05$

6.2.4 DISCUSSION

The present study is the first to develop an anthropometric and physical performance profile of specific individual playing positions in elite young players throughout the U9 to U19 age groups. Previous studies have only examined anthropometric and physical performance characteristics according to playing position in one or a limited number of age groups (Franks et al., 1999; Neto et al., 2003; Philippaerts et al., 2003: Gil et al., 2007).

No positional differences in standing height or body mass were evident in the youngest two age groups (U9 and U10) in the current study. Other studies of young players have reported significant differences to exist between specific playing positions in terms of standing height and body mass (Franks et al., 1999; Gil et al., 2007). However, in both these previously reported studies the youngest players investigated were 14 years of age and no other studies in the literature have reported on positional differences in such young age groups as those examined in the present study (U9 and U10). It may well be the case that any positional differences at such an early age are not to be expected given the fact that under the technical regulations for English soccer academies (Wilkinson, 1997) players only take part in small sided games up to the age of 11 years.

Consistent with previous findings, including Franks and colleagues (1999), Malina and colleagues (2000) and Gil and colleagues (2007), the present study indicated positional differences in standing height and body mass to be evident in the U11 to U19 age groups. In a study of 241 non-elite Spanish players aged 14 to 21 years, goalkeepers were found to be significantly taller and heavier than the outfield players (Gil et al., 2007). Similarly in the current study goalkeepers and centrebacks in several age groups were found to be taller and heavier in comparison to the other playing positions. For example, on average in the U17 age group, goalkeepers and centrebacks were 11.5 cm and 9.6 cm taller than the fullbacks, respectively. This finding clearly supports the suggestion that tall players have an advantage in certain playing positions and consequently are oriented towards these roles within a team, most notably goalkeeper, centreback and central forward (Reilly, Bangsbo and Franks, 2000). Furthermore, the current results would suggest that elite young players are being prepared for specific positional roles from an early age based on their suitability in terms of stature.

The fact different types of forward player (central and wide) were not distinguished between in the present study may be why forwards were found to be shorter than goalkeepers and centrebacks, particularly in the older age groups (U15 to U19). In relation to this Bangsbo and Mischalik (2002) noted a large range in the standing height of 14 elite senior Danish forward players (1.67 m to 1.90 m), suggesting that this variability may influence the tactical role allocated to an individual player within a team. It was interesting to note in the current study that a larger range in standing height in the oldest age group (U19) was found in forwards (17.1 cm) as opposed to centrebacks (6.9 cm) and goalkeepers (10.5 cm). This finding may emphasise the point that forwards may be asked to perform more diverse tactical roles in comparison to the more regimented roles afforded to centrebacks and goalkeepers.

The type of positional roles used to group players varies across different studies and may account for some of the disparity in findings reported in the literature. In the current study a distinction was made between centrebacks and fullbacks, whereas some researchers have grouped them together as defenders (Bloomfield et al., 2003; Neto et al., 2003; Philippaerts et al., 2003; Gil et al., 2007). For example, Neto and colleagues (2003) found no differences in standing height and body mass to exist between 18 year old Brazilian players who were grouped as defenders, midfielders and forwards. However, similar to the positional classification in the present study other studies have distinguished between centrebacks and fullbacks in the analysis (Davis, Brewer and Atkin, 1992; Di Salvo and Pigozzi, 1998; Bangsbo and Michalsik, 2002; Neto, Nunes and Hespanhol, 2007). In the study of Brazilian U15 players, significant differences in standing height were observed with central defenders (centrebacks) being taller in comparison to lateral defenders (fullbacks), defensive midfielders, offensive midfielders and forwards (Neto, Nunes and Hespanhol, 2007). Furthermore, based on results from elite Danish players, fullbacks were found to have significantly higher $\dot{V}O_{2max}$ values than centrebacks (Bangsbo and Michalsik, 2002). Given the fact that differences in stature, physical performance and game demands have been observed to exist between fullbacks and centrebacks such positional groupings would appear more acceptable than merely classifying both positions as defenders.

The variation in stature across different playing positions was further emphasized in the current study when comparisons were made to British 1990 growth reference centiles (Cole et al., 1998). The average standing height of the goalkeepers and centrebacks was above the 70th centile from the U11 to U19 and U14 to U19 age groups, respectively. The U17 goalkeepers were found to be on the 89th centile, whilst the U16 centrebacks were on the 84th centile. These observations underline the relative importance being placed on players with a tall stature in the positions of goalkeeper and centreback in the modern game. At the other end of the scale, the average standing height of fullbacks and midfielders was on the 51st centile from the U9 to U19 age groups. In fact the average standing height was below the 50th centile in a number of age groups in the fullbacks (U10, U11, U13, U16, U17 and U18) and midfielders (U11, U13, U15 and U17). The current findings for elite young players are in line with the relative heterogeneity in body size that has been observed to be evident in groups of elite senior players (Reilly et al., 2000). Despite suggestions of a tendency to recruit taller players (Shephard, 1999), the results from the present study would suggest that stature is not a pre-requisite for the positions of fullback and midfielder, which may suggest that other attributes are of more importance in these positions.

In the present study no significant differences in vertical jump performance (RJ; CMJ; CMJA) were found between playing positions in the oldest three age groups (U17; U18; U19). An earlier analysis of 61 first team and 28 reserve team players from the English Premier League also revealed no differences in vertical jump height between different playing positions (Dunbar and Treasure, 2003). However, the current study did reveal that forward players jumped significantly higher in comparison to the other playing positions in some of the younger age groups (U12; U13; U16). This finding is contrary to that reported for Brazilian U15 players where no difference in vertical jump (RJ; CMJ) was observed between different playing positions (Neto, Nunes and Hespanhol, 2007). Although in a more recent study of non-elite Spanish players (14 to 21 years) the forwards were found to have the highest vertical jump (Gil et al., 2007). The same authors also suggested that lower extremity power was one of the most important factors in the selection process for forward players. The finding of superior vertical jump performance in the present study, particularly in the younger forward players would appear to add some support to this suggestion made by Gil and colleagues (2007).

The goalkeepers sprint (10 m and 20 m) and agility performance in the current study was found to be significantly slower in comparison to the outfield players throughout a number of age groups. Gil and colleagues (2007) also found the goalkeepers to be comparatively slower in terms of sprint speed and agility. The authors, in order to explain this difference suggested that as both the sprint and agility test were conducted over a distance of 30 m they were not specific to goalkeepers who more commonly sprint between 1 and 12 m during a game. However, the same explanation is not supported by the present findings as a shorter sprint test (10 m) was included in the test battery and the goalkeepers were still found to be slower in comparison to the outfield players, in particular the forwards. It may be suggested that the extra height and body mass of the goalkeepers had an adverse effect on their ability to accelerate quickly over 10 m. The fact that the centrebacks who were of a similar standing height and body mass to the goalkeepers were only significantly faster than the goalkeepers over 10 m in the U9 age group would appear to support this suggestion.

The current study revealed that the forward players were faster in the 10 m and 20 m sprint in comparison to the other outfield players in a small number of age groups. For example, the forwards were significantly faster than the midfield players over the 20 m sprint in the U13 and U16 age groups. Other researchers have found the forward players to be the fastest in terms of sprint speed (Sena et al., 1997; Gil et al., 2007). Based on the fact that forwards and fullbacks have been found to sprint significantly longer than centrebacks and midfielders in a game (Mohr, Krustrup and Bangsbo, 2003), differences in the sprint ability of different outfield playing positions may be expected. However, a study of 66 English international U16 players found no significant differences to exist between different playing positions in 15 m and 40 m sprints (Franks et al., 1999). Furthermore, in a study of German professional and amateur players no differences in sprint speed (5 m; 10 m; 20 m; 30 m) were found to exist between offensive and defensive players (Kollath and Quade, 1993). The authors implied that in elite professional and amateur soccer the speed requirement of offensive and defensive players is similar and therefore they should be paralleled in training. Similarly in relation to this suggestion no significant differences were found to exist between the outfield playing positions on the agility test in the present study.

Goalkeepers displayed significantly lower values for estimated $\dot{V}O_{2peak}$ in comparison to the outfield players in the current study. Similar findings have been published by other researchers (Puga et al., 1993; Bangsbo and Michalsik, 2002; Gil et al., 2007). The physical demands placed on goalkeepers during games are different to those experienced by outfield players (Reilly et al., 1990). As a result goalkeepers' training is fundamentally different to that undertaken by outfield players. With less emphasis placed on endurance performance the finding of lower values of estimated $\dot{V}O_{2peak}$ in goalkeepers is to be expected. In the present study no significant differences in estimated $\dot{V}O_{2peak}$ were observed between the outfield playing positions. This finding is in line with a previous study on non-elite young Spanish players (Gil et al., 2007). However, other researchers who have studied elite senior players have suggested that fullbacks and midfielders have higher $\dot{V}O_{2peak}$ values than centrebacks (Bangsbo and Michalsik, 2002). It may be suggested that the elite young players investigated in the present study have yet to experience a significant amount of position specific training which may lead to the differences in endurance performance observed at the senior level.

In conclusion, the present study has demonstrated that both anthropometric and physical performance differences exist among specific playing positions in elite young soccer players. Goalkeepers and centrebacks were found to be taller and heavier than other players, emphasising the importance placed on stature in these respective positions in the modern game. Outfield players demonstrated superior physical performance in terms of sprint speed, agility and estimated $\dot{V}O_{2peak}$ in comparison to goalkeepers, whilst a tendency for forwards to display the quickest sprint speeds of the outfield players was revealed.

6.2.4.1 Practical applications

These findings provide normative data for elite young soccer players from the U9 to U19 age groups in relation to specific playing positions. The current results provide an invaluable reference tool for all those involved in the development of elite young soccer players. Coaches may use the data to assist in the assessment of a players suitability in terms of their anthropometric and physical performance characteristics for specific playing positions.

6.3 A COMPARISON OF ANTHROPOMETRIC AND PHYSICAL PERFORMANCE CHARACTERISTICS AMONG DIFFERENT ETHNIC GROUPS IN ELITE CHILD AND ADOLESCENT SOCCER PLAYERS

6.3.1 INTRODUCTION

Professional soccer in England first saw the introduction of Black players during the late 1960s and early 1970s, (Maguire, 1988). In 1979 Viv Anderson became the first Black player to play for England at full international level. Today black players appear in significant numbers on the first team squads of professional teams. On the 10th June 2009 Carlton Cole became the 58th Black player to appear for England. Viv Anderson was the 936th player to appear for England since their first match in 1872, whilst Carlton Cole was the 1159th player to appear for England. Based on these figures approximately one in four players making their England debut since the appearance of Viv Anderson have been Black. A significant milestone was reached on the 28th May 2005 during a friendly fixture against the United States of America when more Black players started an England game than White players. This game saw seven Black players in the starting eleven, with a further two Black players appearing as substitutes.

Maguire (1988) first discussed the overrepresentation of Black players in English soccer during the 1985-1986 playing season. During this season the Black players were found to account for 7.7% of the 1445 registered professional players despite the fact that Black Caribbeans accounted for only 1.4% of the total population according to the 1981 census. A number of authors have sought to explain the phenomenon of a disproportionate number of Black professional athletes. In general, critical sociological work has dismissed suggestions that natural race-based differences account for the superior performance of black athletes in many sports. For example, Lapchick cited in Christie (1996, pp. C16) has argued, “We have spent six decades since Jessie Owens trying to prove scientifically there’s some difference between Black and White athletes to explain the Black athlete’s succeeding dominance to the point it is today………There's never been one study to prove the racial theory in sport, the fact we try to prove it is a reflection we are uncomfortable in White-dominated society. We need some explanation, so we can accept that Blacks are better physical specimens, while we contend that Whites are intellectual". Other authors, including Entine (2000) have challenged such premises, suggesting that there is an abundance of evidence, both scientific and anecdotal, showing that the dominance of Black athletes in elite level sport is attributable in part to 'superior' genes. In line with this suggestion, Kane (1971, pp.72-83) commented that, "Environmental factors have a great deal to do with excellence in sport……….but so do physical differences and there is an increasing body of scientific opinion which suggests that physical differences in the races might well have enhanced the athletic potential of the Black athlete in certain sports".

Evidence has been presented that supports the contention that in English professional soccer Black players are assigned to playing positions on the basis of racial stereotypes of abilities (Maguire, 1988). Maguire (1988) found Black players to be underrepresented in the goalkeeper and midfield positions but overrepresented in forward and fullback positions, positions that stress speed and quickness, the qualities that are often associated with Blacks. Similar findings have been reported by North American research in American football (Chu and Segrave, 1983), basketball (Curtis and Loy, 1978) and baseball (Eitzen and Sanford, 1975) where the allocation of position by race has been explained by socially constructed racial discrimination. However, there are no studies that have reported on the anthropometric and physical performance of elite senior or elite young players from different ethnic groups.

The aim of the present study was to describe the ethnic composition of the elite young players and their playing positions in English professional soccer academies and to examine differences in anthropometric and physical performance characteristics between the respective ethnic groups. The hypothesis to be tested was that elite young Black players will perform better than elite young White players on soccer specific physical performance tests.

6.3.2 METHODS

6.3.2.1 Participants

Participant information is provided in section 3.3.4.

6.3.2.2 Procedures

A detailed description of the procedures and physical performance testing protocol can be found in sections 3.3 and 3.4.

6.3.2.3 Statistical analysis

Data were analysed using SPSS (Version 16.0, Chicago, Illinois, USA). Descriptive statistics were calculated. One-way analysis of variance (ANOVA) was used to investigate differences anthropometric and physical performance variables between the different ethnic groups. When a significant ethnic group effect was found a Tukey post hoc test was used to test differences among means. A chi-square test was used to test the observed and expected playing position distribution within the ethnic groups. Statistical significance was accepted at the 95% confidence level ($p<0.05$). Values are reported as mean (±SD).

6.3.3 RESULTS

6.3.3.1 Ethnic group characteristics

The majority (85.4%) of the 2,252 academy players studied were classified as White in terms of ethnic group (Table 6.3.1). Black Caribbean (7.8%) and Black African (5.2%) were the second and third largest ethnic groups, respectively (Table 6.3.1). The rest of the ethnic groups (Black Other; Indian; Pakistani; Bangladeshi; Chinese; Other) accounted for only 1.6% of the academy population studied (Table 6.3.1). For this reason the remainder of the analysis was restricted to the White, Black Caribbean and Black African ethnic groups which constituted 98.4% of the academy population studied.

Table 6.3.1. Ethnic distribution of academy population studied by age group including population breakdown for England and Wales (Census 2001).

Age Group	Ethnic Group (n)									
	White	Black Caribbean	Black African	Black Other	Indian	Pakistani	Bangladeshi	Chinese	Other	Totals
U9	169	8	6							183
U10	181	19	6							206
U11	207	17	8	2	1				1	236
U12	235	20	10		1	1			2	269
U13	223	13	8	1					3	248
U14	242	24	15	1	1	1		1	3	288
U15	208	20	19	2				1	2	252
U16	160	18	13	2					1	194
U17	99	13	19	1				1	3	136
U18	137	14	9		1				1	162
U19	63	10	4						1	78
Total (n)	1924	176	117	9	4	2	0	3	17	2252
Total (%)	85.4	7.8	5.2	0.4	0.2	0.1	0	0.1	0.8	100
	Breakdown for England and Wales									
Total (%)	91.3	1.1	0.9	0.2	2	1.4	0.5	0.4	2.1	100

6.3.3.2 Anthropometric characteristics

The chronological age of each ethnic group was similar in all the age groups studied (U9 to U19) (Table 6.3.2). In the younger age groups (U9 to U13) standing height was lowest in the White players, although Black Caribbean and Black African players were only found to be significantly taller in the U12 and U13 age groups, respectively ($p<0.05$; Table 6.3.2). In the majority of the age groups body mass was lowest in the White players, although Black African and Black Caribbean players were only found to be significantly heavier in the U9 and U18 age groups, respectively ($p<0.05$; Table 6.3.2). BMI values were slightly lower in the White players in most age groups, but significant differences were only found for the U14 ($p<0.05$) and U17 ($p<0.05$) age groups where the Black African players had significantly higher BMI values than the white players (Table 6.3.2). Ectomorphy and Reciprocal Ponderal Index values were similar for White, Black African and Black Caribbean players in all age groups, the only exception being the lower values of the U14 Black African players in comparison to the White players ($p<0.05$; Table 6.3.2).

Table 6.3.2. Anthropometric characteristics of players from different ethnic groups by age group (mean±SD).

	Ethnic Group	Age Group										
		U9	U10	U11	U12	U13	U14	U15	U16	U17	U18	U19
Chronological Age (years)	White	9.2±0.4	10.2±0.3	11.2±0.3	12.2±0.3	13.2±0.3	14.1±0.3	15.2±0.4	16.1±0.4	17.2±0.3	18.1±0.4	19.1±0.3
	Black African	9.1±0.4	10.1±0.3	11.3±0.3	12.2±0.2	13.3±0.2	14.1±0.3	15.2±0.3	16.0±0.2	17.1±0.4	18.1±0.3	19.0±0.2
	Black Caribbean	9.1±0.5	10.4±0.2	11.0±0.4	12.1±0.4	13.3±0.3	14.3±0.3	15.1±0.4	16.0±0.4	17.0±0.4	18.1±0.4	19.0±0.4
Standing Height (cm)	White	134.9±5.3	139.9±5.2	145.0±6.8	151.1±7.4	157.2±8.6	166.4±8.3	172.0±8.0	176.1±5.9	178.3±7.0	178.8±5.7	178.9±5.7
	Black African	139.0±5.2	141.1±11.6	148.9±6.0	153.1±7.4	165.6±9.4[a]	166.3±9.2	169.7±8.0	177.7±6.7	178.6±5.9	177.6±5.1	182.5±5.4
	Black Caribbean	138.6±4.9	143.0±6.3	146.2±6.5	156.2±8.2[b]	160.1±6.8	168.0±9.6	173.9±8.0	173.9±5.5	177.5±5.3	180.9±6.5	180.2±3.3
Body mass (kg)	White	30.6±3.5	34.0±4.2	37.3±5.5	41.6±6.3	46.5±7.9	55.1±9.1	62.1±8.9	67.0±7.6	70.6±7.7	72.4±6.5	75.3±7.4
	Black African	34.6±3.3[a]	32.7±6.0	41.1±3.3	45.3±8.9	53.6±9.4	59.0±8.3	61.8±12.1	72.6±8.6	73.9±6.9	73.3±8.0	79.6±5.2
	Black Caribbean	33.6±4.4	35.7±4.4	38.8±5.1	44.8±7.5	50.7±7.7	57.6±10.0	65.1±11.0	66.4±6.7	70.6±8.2	77.3±8.8[b]	73.8±6.1
BMI	White	16.8±1.3	17.3±1.5	17.7±1.6	18.1±1.6	18.7±1.8	19.8±1.8	20.9±1.9	21.6±1.8	22.2±1.4	22.6±1.6	23.5±1.9
	Black African	17.9±0.9	16.3±1.1	18.5±1.2	19.1±2.4	19.4±1.6	21.3±2.1[a]	21.2±2.7	22.9±1.5	23.1±1.4[a]	23.2±1.6	23.9±1.1
	Black Caribbean	17.4±1.2	17.4±1.4	18.1±1.7	18.2±1.7	19.7±2.1	20.3±2.4	21.4±2.2	22.0±2.0	22.3±1.7	23.6±2.0	22.7±1.6
Ectomorphy	White	3.1±0.9	3.1±0.9	3.3±0.9	3.4±0.9	3.5±1.0	3.5±0.8	3.3±0.9	3.2±0.9	3.0±0.7	2.9±0.8	2.5±0.9
	Black African	2.7±0.6	3.8±1.1	3.0±0.9	3.0±1.1	3.7±0.6	2.8±1.2[a]	3.0±1.0	2.7±0.6	2.6±0.7	2.5±0.7	2.5±0.6
	Black Caribbean	2.9±0.5	3.3±0.9	3.1±1.0	3.7±1.0	3.2±1.1	3.4±1.3	3.2±0.9	2.9±1.0	2.9±0.7	2.6±0.9	2.9±0.7
Reciprocal Ponderal Index	White	43.2±1.3	43.3±1.2	43.5±1.3	43.7±1.3	43.9±1.4	43.9±1.1	43.6±1.3	43.4±1.2	43.2±1.0	43.0±1.2	42.4±1.2
	Black African	42.7±0.8	44.2±1.5	43.2±1.3	43.2±1.5	44.1±0.8	42.8±1.7[a]	43.2±1.4	42.7±0.9	42.6±0.9	42.5±1.0	42.4±0.9
	Black Caribbean	43.0±0.7	43.5±1.3	43.3±1.4	44.1±1.3	43.4±1.5	43.7±1.8	43.4±1.2	43.0±1.4	43.0±1.0	42.5±1.3	43.0±1.0

Significant differences between ethnic groups based on one-way ANOVA and post hoc Tukey analysis within age groups.
[a]Significant difference Black African vs. White players $p<0.05$
[b]Significant difference Black Caribbean vs. White players $p<0.05$

6.3.3.3 Physical performance characteristics

Vertical jump performance (RJ; CMJ; CMJA) was higher for Black African and Black Caribbean players in comparison to the White players, except in U15, U17 and U19 (RJ), U11 and U19 (CMJ) and U11 and U19 (CMJA) ($p<0.05$; Figures 6.3.1; 6.3.2; 6.3.4). No significant differences in vertical jump performance (RJ; CMJ; CMJA) were found to exist between the Black African and Black Caribbean players in any of the age groups (U9 to U19) (N.S.; Figures 6.3.1; 6.3.2; 6.3.4).

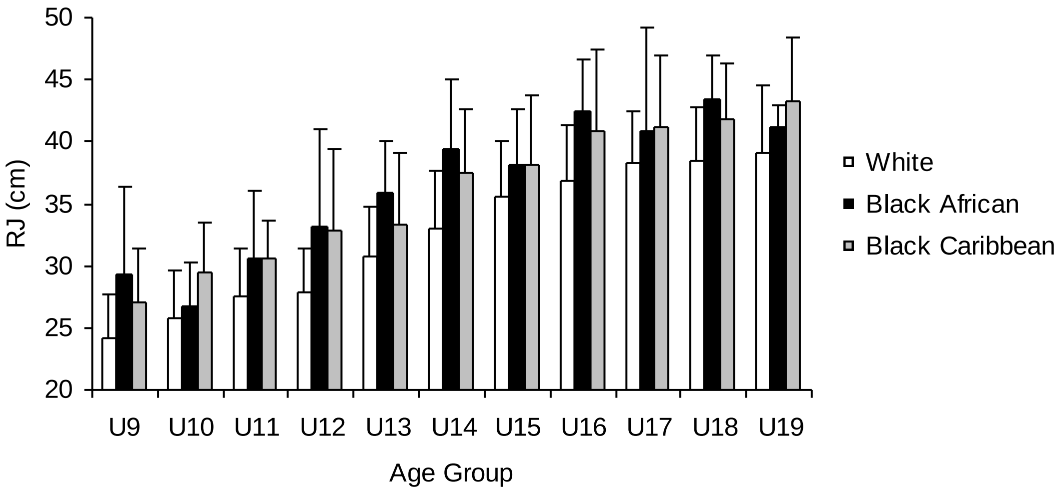


Figure 6.3.1. RJ performance of players from different ethnic groups by age group (mean±SD).
Significant differences between ethnic groups based on one-way ANOVA and post hoc Tukey analysis within age groups.
[a]Significant difference Black African vs. White players $p<0.05$
[b]Significant difference Black Caribbean vs. White players $p<0.05$

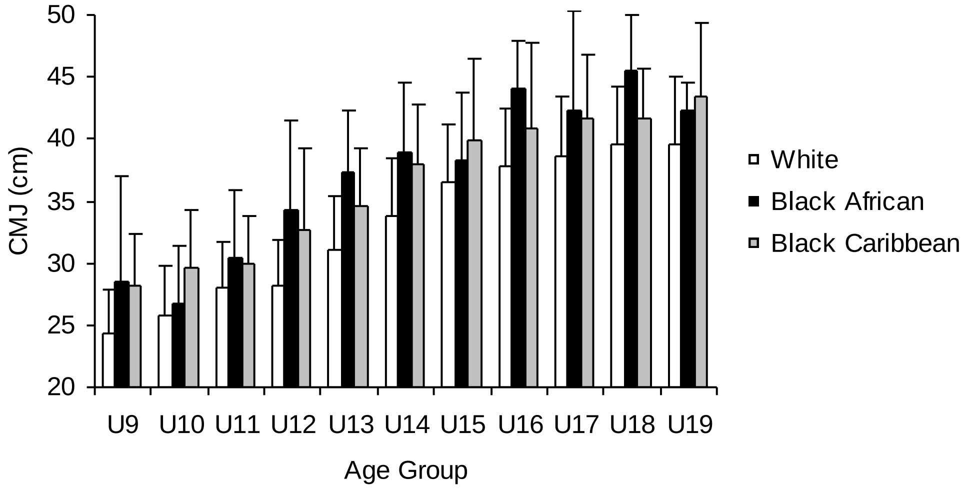


Figure 6.3.2. CMJ performance of players from different ethnic groups by age group (mean±SD).
Significant differences between ethnic groups based on one-way ANOVA and post hoc Tukey analysis within age groups.
[a]Significant difference Black African vs. White players p<0.05
[b]Significant difference Black Caribbean vs. White players p<0.05

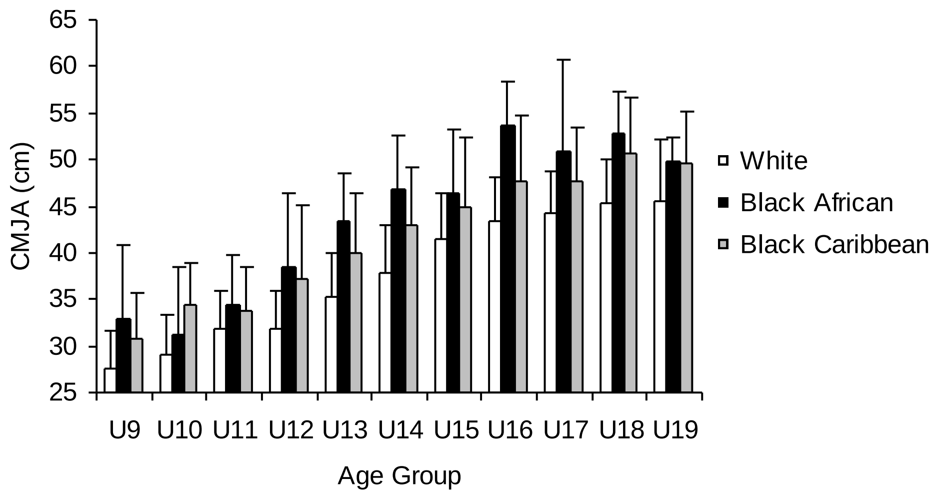


Figure 6.3.3. CMJA performance of players from different ethnic groups by age group (mean±SD).
Significant differences between ethnic groups based on one-way ANOVA and post hoc Tukey analysis within age groups.
[a]Significant difference Black African vs. White players p<0.05
[b]Significant difference Black Caribbean vs. White players p<0.05

Significant differences in sprint performance between the Black African and Black Caribbean players in comparison to the White players were found in four age groups (U10; U12; U14; U18; $p<0.05$) in the 10 m sprint and six age groups (U10; U12; U14;

U16; U17; U18; p<0.05) in the 20 m sprint (Figures 6.3.4 and 6.3.5). In terms of agility performance there was a significant difference only for the U14 age group where the Black Caribbean players were faster than the White players (p<0.05; Figure 6.3.6).

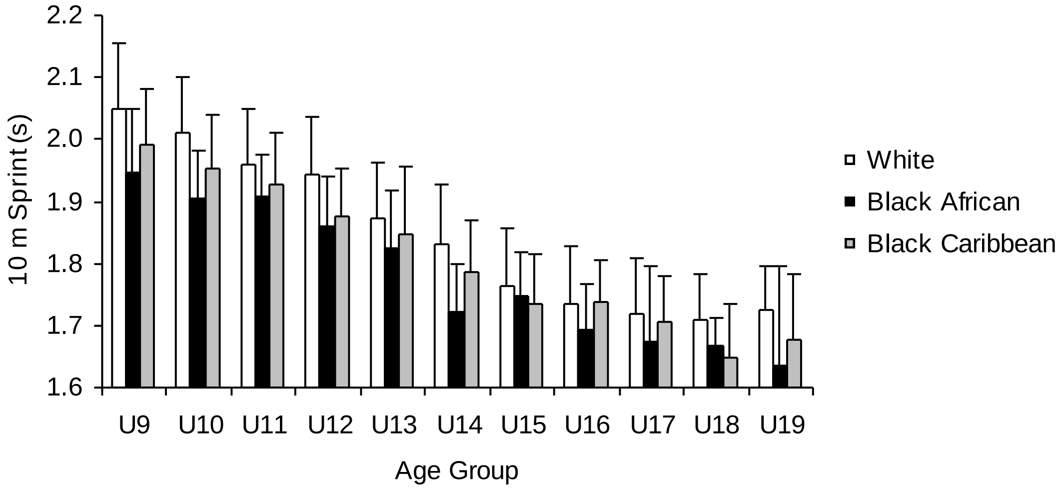


Figure 6.3.4. 10 m Sprint performance of players from different ethnic groups by age group (mean±SD).
Significant differences between ethnic groups based on one-way ANOVA and post hoc Tukey analysis within age groups.
[a]Significant difference Black African vs. White players p<0.05
[b]Significant difference Black Caribbean vs. White players p<0.05

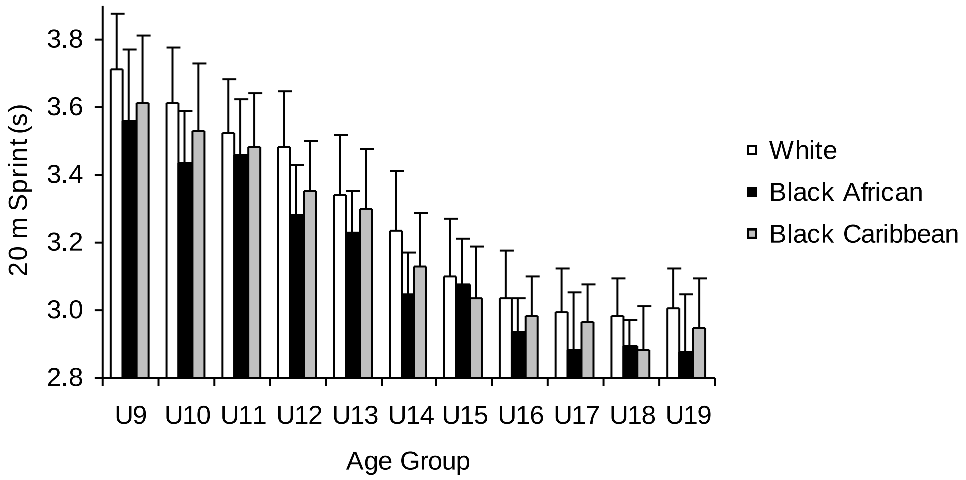


Figure 6.3.5. 20 m Sprint performance of players from different ethnic groups by age group (mean±SD).
Significant differences between ethnic groups based on one-way ANOVA and post hoc Tukey analysis within age groups.
[a]Significant difference Black African vs. White players p<0.05
[b]Significant difference Black Caribbean vs. White players p<0.05

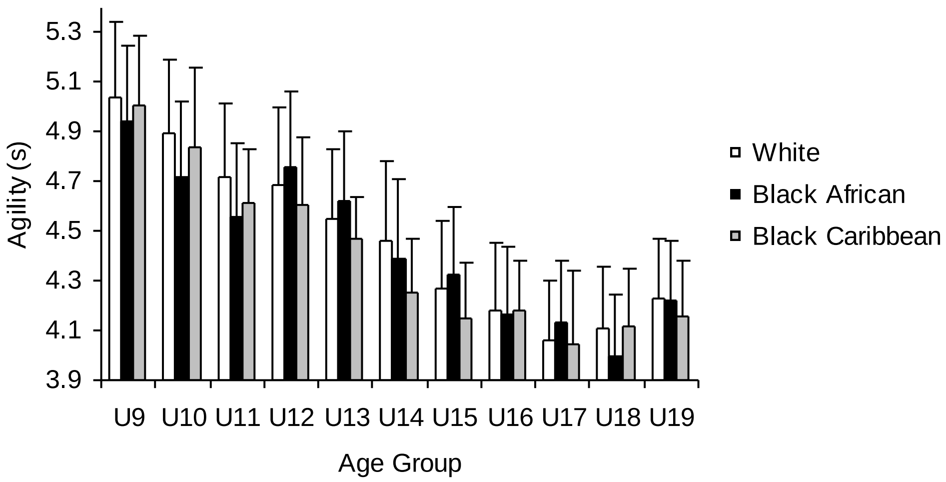


Figure 6.3.6. Agility performance of players from different ethnic groups by age group (mean±SD).
Significant differences between ethnic groups based on one-way ANOVA and post hoc Tukey analysis within age groups.
[a]Significant difference Black African vs. White players p<0.05
[b]Significant difference Black Caribbean vs. White players p<0.05

No significant differences in estimated $\dot{V}O_{2peak}$ were found to exist between the different ethnic groups studied (N.S.; Figure 6.3.7).

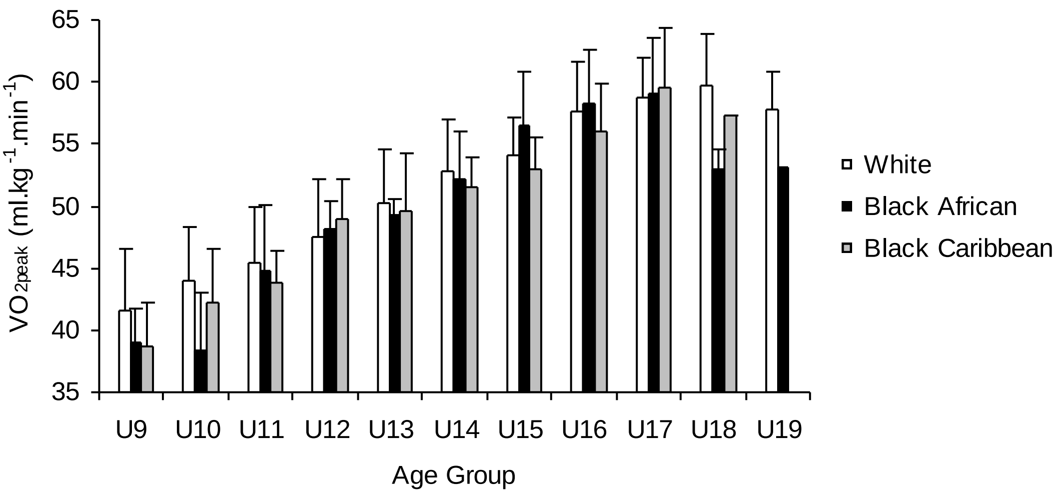


Figure 6.3.7. Estimated $\dot{V}O_{2peak}$ of players from different ethnic groups by age group (mean±SD).

6.3.3.4 Positional characteristics

The relative distribution of White players across the different playing positions revealed most to be midfielders (35.3%), with goalkeepers accounting for 8.9% of the group, which was in line with the expected playing position distribution for academy players (Table 6.3.3). Most Black Caribbean (40.9%) and Black African (35.0%) players were found to be forwards, with only 0.9% and 3.4%, playing in the position of goalkeeper, respectively (Table 6.3.3). The playing position distribution of the Black Caribbean and Black African players was significantly different to expected playing position distribution for academy players ($p<0.001$; Table 6.3.3).

Table 6.3.3. Distribution of players in relation to playing position and ethnic group.

Playing Position	Ethnic Group						Total for all ethnic groups (expected distribution)	
	White		Black African*		Black Caribbean*			
	n	%	n	%	n	%	n	%
Goalkeeper	171	8.9	1	0.9	6	3.4	179	7.9
Fullback	266	13.8	14	12.0	20	11.4	306	13.6
Centreback	291	15.1	17	14.5	11	6.3	325	14.4
Midfielder	679	35.3	32	27.4	53	30.1	775	34.4
Forward	346	18.0	41	35.0	72	40.9	468	20.8
Multi-Positional	171	8.9	12	10.3	14	8.0	199	8.8
Total	1924		117		176		2252	
X^2	10.5		21.0		48.8			
P	<0.06		<0.001		<0.001			

*Significant difference between actual and expected playing position distribution based on chi-square analysis.

6.3.4 DISCUSSION

In the present study, anthropometric, physical performance and positional characteristics were compared across three ethnic groups (White; Black African; Black Caribbean) in young elite academy soccer players. Some differences in the anthropometric characteristics of the White players and the Black African and Black Caribbean players were found to exist. Better physical performance of Black African and Black Caribbean players in comparison to White players was demonstrated on several performance tests across a number of the age groups studied (U9 to U19). Furthermore, a larger proportion of Black African and Black Caribbean players were found to be forward players.

White players accounted for the majority (85.4%) of the 2,252 academy players studied. A greater percentage of White players may have been expected given that 91.3% of the population in England and Wales are White (Census 2001). Black Caribbean and Black African players accounted for 7.8% and 5.2% of the academy population in the current study, respectively. This is despite the fact that Black Caribbeans and Black Africans accounted for only 1.1% and 0.9% of the population of England and Wales according to the 2001 Census data. These findings clearly highlight an overrepresentation of Black Caribbean and Black African players in this elite group of academy players. The overrepresentation of Black players in the professional English soccer leagues has been reported previously (Maguire, 1988). Maguire (1988) noted that Black Caribbeans accounted for only 1.4% of the general population in 1981 whilst Black players made up 7.7% of players in the English Football League during the 1985-1986 playing season. However, to date the present study is the first study to have demonstrated this phenomenon of overrepresentation of Black players in a group of young elite academy soccer players. The present study also highlights the under representation of Asian players in this population of elite academy soccer players. In England and Wales, Indians and Pakistanis account for 2.0% and 1.4% of the population, respectively (Census 2001). However, in the group of academy players studied Indians and Pakistanis made up only 0.2% and 0.1% of the population, respectively.

The current study indicated a trend for the Black Caribbean and Black African players to be taller than the White players in the younger age groups. Body mass was also found to be lowest in the White players in the majority of age groups studied. These findings would appear to support the suggestion that the timing of sexual maturation in Black boys is earlier than in White boys (Sun et al., 2004). Scientific evidence relating to anthropometric differences between Blacks and Whites can be traced back to the 1930s. An early study of 51 Black and 51 White male students found significant differences in bodily proportions between the Black and White students (Metheny, 1939). Metheny (1939) suggested that the longer, heavier arm of Blacks is able to develop greater momentum assisting in jumping whilst the longer legs and narrower hips of Blacks would aid running, permitting longer strides and less angular reaction to the forward stride. More recently Zajac and colleagues (2000) reported that the arm span of Black Polish Basketball players was greater than the Whites. In a study of 137 athletes at the 1960 Rome Olympics Tanner (1964) concluded that large and significant racial differences among track and field performers may have enhanced the athletic potential of Blacks in particular events like the sprints, high jump and long jump, while inhibiting their performance in events such as the marathon. This suggestion of an anthropometric athletic advantage held by Black athletes was given further support by Malina and colleagues (1987) who found Black youths to have longer absolute and relative lower extremities than their White counterparts. Similarly, the ratio of leg length to standing height has been reported to be significantly greater in Blacks compared with Whites (Takashi et al., 1999). However, Takashi and colleagues (1999) found no differences to exist between Blacks and Whites in relation to muscle architecture, concluding that whilst there may be ethnic differences in anatomical stature, muscle architecture is likely to be independent of race. Although no anthropometric measures of this nature were obtained in this study, the findings of previous studies which have highlighted subtle differences in the physique of Black and White athletes are important to note when interpreting the differences in physical performance demonstrated in the current study.

In terms of physical performance the present results clearly display the significantly better vertical jump ability of the Black players in comparison to the White players across the majority of the age groups studied (U9 to U19). For example, in the U16 age group the average height for the CMJA recorded for Black African players was 10.5 cm (24%) higher than that of the White players. It would appear that such differences in vertical jump performance would provide Black players with a distinct advantage on the field of play, for example when contesting aerial duels for the ball. Previously it has been suggested that Black infants are advanced in terms of motor development during the first two years of life, and that Black children of school age perform consistently better than White children in vertical jump and sprint tests (Malina, 1988). Blacks have also been reported to outperform Whites on a vertical jump and 20 m sprint test in one of the few studies on elite athletes from the Polish Basketball League (Zajac et al., 2000). Evidence of this nature is in accordance with the current finding that on average young elite Black players are able to jump higher than their White counterparts. Most authors suggest that the differences in sprint speed and vertical jump performance observed between Blacks and Whites is related to anthropometric and skeletal muscle characteristics (Carter, 1984; Zajac et al., 2000). It may be the case that anthropometric differences that have been reported to exist between Blacks and Whites (Metheny, 1939; Zajac et al., 2000) provide Blacks with a biomechanical advantage in jumping and running. These suggestions might offer some explanation for the current findings. However, the only anthropometric measurements taken in this study were standing height and body mass and therefore a definitive anthropometric explanation for the present findings is not possible.

Similar to the findings of Zajac and colleagues (2000) the better vertical jump ability of the young Black players in the current study correlates with the faster sprint times that were recorded over 10 m and 20 m in comparison to the young White players. The present results further highlight the relative importance of explosive strength for sprint performance something which has previously been described by Tschopp and Hubner (2007) in a study of 37 elite Swiss junior players. Tschopp and Hubner (2007) noted that the fastest players had significantly higher maximal power output relative to body mass in vertical jump (CMJ and SJ) performance, suggesting a higher level of neuromuscular function. In the present study the average 20 m sprint time for Black African players was 0.2 s faster than that of the White players in the U12 age group. This would equate to the Black African players being on average 1.15 m ahead of the White players after sprinting 20 m. When put into the context of a game such an advantage could be crucial, it is often stated that the ability to accelerate can decide important outcomes of the game (Svensson and Drust, 2005).

Much has been written about the better performance of Black athletes in comparison with White athletes and athletes from other ethnic groups in relation to sprint events. For example, Samson and Yerles (1988) highlighted that in terms of Olympic performance Black athletes won more medals than their White counterparts in the 100 m, 200 m and 400 m events. Others, such as Kane (1971) in the article “An assessment of Black is best” have presented evidence supporting the notion that outstanding athletic performances in certain sports are based on racial characteristics indigenous to the Black population. However, it should be noted that some researchers have questioned any proposed connection between ethnically linked physical characteristics and Black athletic superiority because of methodological problems and debatable assumptions about the differences between the respective ethnic groups. For instance, Edwards (1971, pp. 35) stated that there exists “more differences between individual members of any one racial group than between any two groups as a whole”. Instead, Edwards (1971) concludes that a variety of societal conditions are responsible for the high value that young Blacks placed on sport which in turn has led to a disproportionate number of talented Blacks being channelled into sport participation. However, given the overrepresentation of Black athletes in particular sports Wiggins (1989, pp. 185) argues that, "The spirit of science necessitates that academics continue their research to determine if the success of Black athletes is somehow the consequence of racially distinctive chromosomes. The worst thing to happen would be for researchers to refrain from examining the possible physical differences between Black and White athletes for fear they would be transgressing an established political line or labelled racist. Like all areas of research, the topic of Black athletic superiority needs to be examined from a broad perspective and not from a preconceived and narrowly focused vantage point".

One physical argument that has been suggested to explain why Black athletes may perform better than White athletes in those sports requiring speed and power is that Black athletes are endowed with a greater proportion of fast-twitch muscle fibres (Wiggins, 1989). Evidence to support this suggestion is somewhat limited with the exception of an earlier study comparing the skeletal muscle characteristics in sedentary Black and Caucasian males (Ama et al., 1986). It was noted that the Caucasians had a higher percent Type I and a lower percent Type IIa fibres in comparison to the Black Africans, whilst the enzyme activities of the anaerobic energy supply pathways were higher in the Black Africans (Ama et al., 1986). Whist the authors concluded that Black individuals are in terms of skeletal muscle characteristics well endowed for sport events of short duration it should be noted that the nature of the results was somewhat limited, being based on only 23 Black and 23 Caucasian sedentary subjects. A further study by Ama and colleagues (1990) revealed that sedentary Black subjects experienced a greater degree of fatigue than sedentary Whites during high intensity exercise lasting longer than 30 seconds. It was suggested that this may be the result of the Blacks having, on average, more Type II muscle fibres and higher muscle enzyme activities of the anaerobic energy supply pathways than the skeletal muscles of the Whites. However, no differences in peak power output between the Blacks and Whites were noted by Ama and colleagues (1990) which would appear contradictory with the common observation that Black athletes are generally more successful than White athletes in running events of short duration.

In the present study there was a trend for the Black players to be slightly faster than the White players on the Agility test, although the differences observed were not as great as those recorded in the vertical jump and sprint tests. This finding may be explained by the contention that agility performance is a product of a combination of physical qualities, including, strength, speed, balance and co-ordination (Draper and Lancaster, 1985), whereas vertical jump and sprint speed are a more direct manifestation of muscle strength and power. Zajak and colleagues (2000) found the Black Polish basketball players to be significantly faster than the White players on a shuttle run that was used as a test of agility. However, the nature of the shuttle run test used by Zajak and colleagues (2000) to measure agility, four 10 m sprints interspersed by three turns, would appear to be more closely associated with straight line sprint speed than the more complex agility test performed in the current study.

A trend of higher estimated $\dot{V}O_{2peak}$ values in the White players compared to the Black players was apparent in the present study, although none of the differences were significant. An observation of this nature may be linked to the suggestion of greater proportions of slow twitch muscle fibres in the skeletal muscle of sedentary Whites (Ama et al., 1986). Zajak and colleagues (2000) reported significantly higher $\dot{V}O_{2peak}$ values in White as opposed to Black Polish basketball players (57.1±8.9 vs. 50.8±3.7 $ml.kg.^{-1}min^{-1}$). To explain this difference the authors concluded that the White basketball players may compensate for the lack of explosive strength and speed by developing aerobic capacity to a higher extent. A similar explanation may extend to the young White players in the current study with the relative importance of higher levels of endurance performance being demonstrated by a significant relationship between $\dot{V}O_{2peak}$ values and both distance covered during a game and number of sprints attempted by a player (Smaros, 1980).

The results of the present study clearly demonstrate a disproportionate representation of Black players in certain playing positions within English professional soccer academies. The under representation of Blacks was particularly evident for the goalkeeper position. In addition the Black players were overrepresented in the forward position. The current study suggests that the concept of “stacking” described in relation to the distribution of position occupancy among 111 professional Black English Football League players during the 1985-1986 playing season by Maguire

(1988) was also evident within English professional soccer academies during the 2002-2003, 2003-2004 and 2004-2005 playing seasons. Maguire (1988) suggested that Blacks were overrepresented in positions that stress speed and quickness, contending that Blacks were assigned to positions by White coaches on the basis of racial stereotypes of abilities. Research in American sports has also shown that associating Blacks with the qualities of speed and power is part of a more general stereotyping process (Edwards, 1973).

It has been suggested that televised sport has a powerful role in creating and maintaining images and stereotypes (McCarthy and Jones, 1997). Whannel (1992) suggested that one of the principal ways in which this stereotyping is articulated on television has been in terms of the “natural ability” of the Black athlete. McCarthy and Jones (1997) analysed the language used by television commentators during the coverage of English soccer matches in respect to the race of the players. The authors found evidence of racial stereotyping with excessive positive depictions related to the physicality of the Black players and the psychological characteristics of the White players. McCarthy and Jones (1997) argue that the overrepresentation of Black players in certain playing positions is created largely by the stereotypes relating to their physical attributes, suggesting that the perceived need of a position and the image of the Black player are “locked into a mutually reinforcing set of constraints”. This stereotyping has also been associated with the concept of “centrality”, with Blacks and Whites being assigned to non-central and central positions, which stress physical (strength, speed and quickness) and psychological (leadership, intelligence and emotional control) qualities, respectively (Maguire, 1988). It is difficult to confirm if this concept is evident in the present study as positions were not further classified as being either central or non-central, for example distinguishing between the positions of central midfield and wide midfield. However, the under representation of Black players in the central position of goalkeeper would appear to suggest a degree of “centrality” to be evident in the current study. Although much evidence of racial stereotyping in relation to positional assignment in soccer has been documented the results of present study would appear to suggest it is a direct consequence of the fact that young Black players in professional English soccer academies are faster and more powerful than their White counterparts that results in them being overrepresented in the forward playing position which stresses these same physical qualities.

In conclusion, the present study has shown that Black players are overrepresented in English professional soccer academies. Although few differences where apparent in terms of anthropometric characteristics, there was some evidence that the Black players were taller than the White players particularly in the younger age groups. Better physical performance of the Black players in comparison to White players was most clearly demonstrated on the vertical jump tests across the majority of the age groups studied. Finally, the Black players were found to be overrepresented in the forward playing position but underrepresented in the playing position of goalkeeper.

6.3.4.1 Practical applications

As this study is the first of its kind to date it will help to raise the awareness of practitioners in professional soccer to the differences, particularly in relation to physical performance that exist between Black and White players. A greater appreciation of the respective anthropometric and physical performance characteristics of Black and White players may help to diminish racial stereotyping of abilities.

CHAPTER 7

RELATIVE AGE AND MATURATION

7.1 RELATIVE AGE AND PHYSICAL PERFORMANCE IN ELITE CHILD AND ADOLESCENT SOCCER PLAYERS

7.1.1 INTRODUCTION

In a sporting context the relative age effect describes the observation that greater numbers of performers born early in a selection year are over-represented in junior and senior elite squads compared with what might be expected based on national birth rates (Morris and Nevill, 2007). In England, the selection year for sport and education is traditionally structured between the 1st September of a particular year and the 31st August of the following year. Therefore, children born in September possess almost a one year relative age advantage over children born in August of the following year. Conversely, children born in August will have a one year developmental disadvantage relative to their peers born in September of the previous year.

It is widely acknowledged that a wide variety of factors can and do influence selection and progression in elite sport. Relative age is one factor that does seem to influence high level sports performance (Morris and Nevill, 2007). Previous studies have shown a relative age effect to exist in ice hockey (Boucher and Mutimer, 1994), baseball (Thompson et al., 1991), tennis (Edgar and O'Donoghue, 2005) and soccer (Brewer et al., 1995; Musch and Hay, 1999; Simmons and Paull, 2001; Jimenez and Pain, 2008; Carling et al., 2009; Williams, 2009). For example, the relative age effect was demonstrated in a group of 103 players aged 15 and 16 years of age who were selected for the English Football Association National School, with 71.8% born September to December, 23.4% born January to April and 3.8% born May to August (Brewer et al., 1995). Based on these findings and further observations of 59 Swedish U17 players and 805 English Football Association centres of excellence players from 9 to 16 years of age the same authors concluded that players born in the earliest months of a particular age band dominate elite youth football programmes.

Indeed, the relative age effect is not exclusive to sport with school examination results providing evidence of better performance by the eldest children in a year group compared to their younger peers (Jinks, 1964; Thompson, 1971; Giles, 1993).

In soccer the relative age effect has been suggested to arise from the inevitable difference in physical, emotional and intellectual development between the oldest and youngest children in a particular age group (Jimenez and Pain, 2008). In young players a year's difference in chronological age can be displayed as significant differences in anthropometric variables (height and body mass), physical performance characteristics (speed, strength, muscular power and endurance) and psychological/cognitive abilities (Musch and Hay, 1999; Helsen et al., 2000; Simmons and Paull, 2001). Fundamentally it may well be that 'relatively' older individuals in a group of players are taller, heavier and consequently stronger, faster and more athletic. As a result, during selection trials such players are more likely to catch the eye of selectors, especially in relation to age-disadvantaged peers. Whilst a number of potential explanations for the relative age effect have been put forward, its causes have not been conclusively explained. The key issue therefore remains to ascertain why the relative age effect is prevalent in soccer.

Thus the purpose of the present study is to examine the extent of the relative age effect in English professional soccer academies, its variation throughout different age categories and if such an effect is associated with differences in physical characteristics and performance. The hypothesis to be tested was that the selection process in elite youth soccer currently favours the older and more mature players.

7.1.2 METHODS

7.1.2.1 Participants

Participant information is provided in section 3.3.4. The professional status of all participants over 18 years of age at the end of the 2007/2008 playing season (11.05.08) was sourced from the International Soccer Bank (Neustadt, Germany).

7.1.2.2 Measurement of birth date distribution

The birth date of all participants was recorded and players were then grouped according to the month of the selection period in which they were born. In English

Academy football the selection year begins on the 1st September (Month 1) and ends on 31st August (Month 12). To investigate birth date distribution and the relative age effect, players were divided into one of four groups (1st Quarter: September to November; 2nd Quarter: December to February; 3rd Quarter: March to May; 4th Quarter: June to August) according to their date of birth in the selection year (Helsen et al., 2005). Expected birth date distribution was calculated on the basis of a uniform distribution throughout any twelve month period (Edgar and O'Donoghue, 2005).

7.1.2.3 Procedures

A detailed description of the procedures and physical performance testing protocol can be found in sections 3.3 and 3.4.

7.1.2.4 Statistical analysis

Data were analysed using SPSS (Version 16.0, Chicago, Illinois, USA). A chi-square test was used to test the observed and expected birth distribution across the sample of players. One-way analysis of variance (ANOVA) was used to investigate differences in anthropometric and physical performance variables across the four birth quartiles. When a significant birth quartile effect was found a Tukey post hoc test was used to test differences among means. Standing height and body mass measurements were compared against British 1990 growth reference centiles (Cole et al., 1998) using the LMS method (Cole and Green, 1992). Statistical significance was accepted at the 95% confidence level ($p<0.05$). Values are reported as mean (±SD).

7.1.3 RESULTS

7.1.3.1 Season of birth distribution in English academy players

The birth date distributions by month during the selection year are shown in Table 7.1.1. A relative age effect was evident, with 46.5% and 10.6% of players having birthdates between September - November (1st Quarter) and June – August (4th Quarter), ($p<0.01$; Table 7.1.1). This relative age effect was evident in all academy age groups from U9 to U19 (Figure 7.1.1). The percentage of players born in the 1st Quarter of the selection year ranged from 51.6% to 28.2% in the U13 and U19 age groups respectively (Figure 7.1.1). Conversely, the number of players born in the 4th

Quarter of the selection year ranged from 6.6% to 13.9% in the U9 and U15 age groups respectively (Figure 7.1.1).

Table 7.1.1. Month of birth of English academy players.

Month		n	%	Quarter	n	%
1	September	418	18.6			
2	October	342	15.2		1048	46.5
3	November	288	12.8	1	(561)	(24.9)
4	December	225	10.0			
5	January	205	9.1		580	25.8
6	February	150	6.7	2	(555)	(24.6)
7	March	166	7.4			
8	April	107	4.8		385	17.1
9	May	112	5.0	3	(568)	(25.2)
10	June	87	3.9			
11	July	71	3.2		239	10.6
12	August	81	3.6	4	(568)	(25.2)
				Total	2252	
(Expected birth distribution - n and %)				X^2	672.1	
				P	<0.01	

Significant difference between actual and expected month of birth distribution based on chi-square analysis p<0.01.

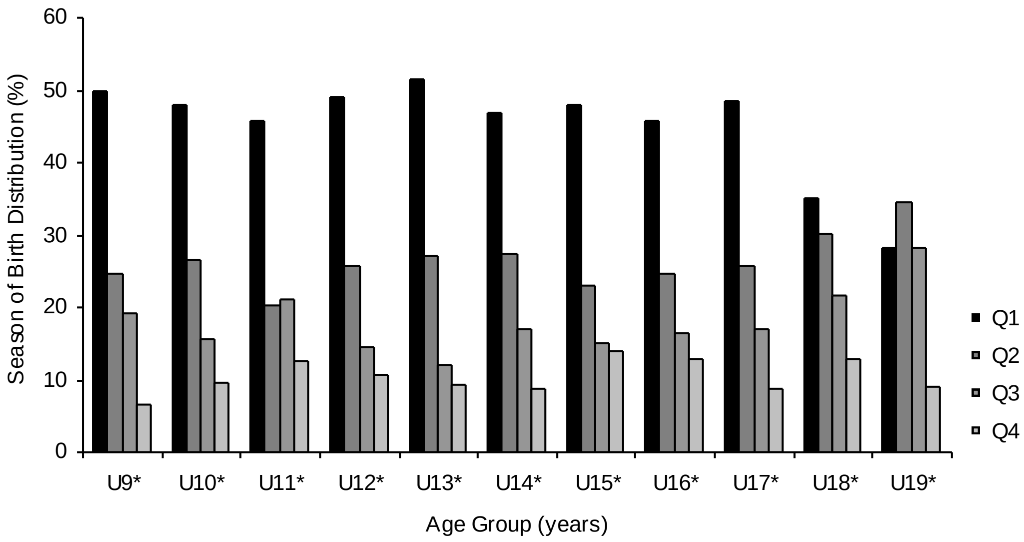


Figure 7.1.1. Season of birth distribution (%) of English academy players by age group.
*Significant difference between actual and expected month of birth distribution (Relative Age Effect) based on chi-square analysis within age groups $p<0.01$.

7.1.3.2 Season of birth and anthropometric characteristics

A number of differences were evident in anthropometric characteristics of players born in different quarters of the selection year (Table 7.1.2). Those players born in the early part of the selection year were taller (U10, U11, U13, U14, U15; $p<0.05$) and heavier (U10, U12, U13, U14, U18; $p<0.05$; Table 7.1.2). Differences in the centile values for standing height (U9, U10, U14; $p<0.05$) and body mass (U9, U14; $p<0.05$) were evident between different quarters of the selection year (Table 7.1.2).

7.1.3.3 Season of birth and physical performance

Some differences in physical performance were evident across the selection year of respective age groups (Table 7.1.3). Players born in the early part of the selection year could jump higher, (RJ – U10, U17, U19; $p<0.05$; CMJA – U9, U10, U19; $p<0.05$), sprint faster (20 m speed - U14, U15; $p<0.05$) and were more agile (U12; $p<0.05$; Table 7.1.3).

7.1.3.4 Season of birth distribution in different sub-groups of players

Differences in the birth distribution of players were evident in relation to playing positions. The position with the highest percentage of players born in the 1st Quarter was centre back (52.9%) compared to fullback (43.1%) with the lowest percentage of players born in the 1st Quarter.

Although a relative age effect was observed in those academy players who have subsequently graduated to become professional players, the effect was not as strong as in comparison to those academy players who did not go on to become professional players (Table 7.1.4).

A relative age effect was evident in junior international players, when the European Union of Football Associations (UEFA) start date of January 1st was used in the analysis as opposed to the English Academy start date of September 1st (Figure 7.1.2).

Table 7.1.2. Anthropometric characteristics of players by quarter of selection year and age group (mean±SD), (including standing height and body mass centiles, Cole et al., 1998).

Age Group	Physical Characteristic	1st Quarter (Sept-Nov)	2nd Quarter (Dec-Feb)	3rd Quarter (Mar-May)	4th Quarter (Jun-Aug)
U9	Standing Height (cm)	135.0±5.6 (47.6±28.2)[a,c]	136.5±5.6 (60.5±24.0)	134.0±5.1 (57.4±24.5)	135.6±3.4 (71.0±20.0)
	Body mass (kg)	30.8±3.9 (55.6±25.1)[a]	31.6±3.6 (66.6±20.7)	29.8±3.5 (59.8±21.6)	30.7±2.3 (72.0±9.9)
U10	Standing Height (cm)	141.6±5.5[b,c] (54.9±25.6)[c]	140.6±5.1[e] (56.2±23.6)[e]	138.6±4.4[f] (52.9±23.8)	134.5±4.7 (37.9±23.2)
	Body mass (kg)	35.1±4.6[c] (60.0±23.7)	33.8±3.6 (59.2±21.3)	33.6±3.5 (62.4±18.4)	31.1±4.2 (51.1±25.4)
U11	Standing Height (cm)	147.1±6.3[b,c] (56.9±26.4)	144.8±7.2 (58.2±27.7)	143.2±6.1 (56.2±26.1)	143.0±7.4 (55.6±29.9)
	Body mass (kg)	38.3±5.3 (50.9±23.7)	37.9±6.1 (58.8±23.9)	36.8±5.2 (62.5±23.4)	35.8±4.5 (60.1±23.4)
U12	Standing Height (cm)	152.3±6.7 (56.6±26.8)	151.7±7.6 (60.3±28.7)	151.1±6.7 (61.8±31.4)	148.5±6.7 (57.8±31.4)
	Body mass (kg)	42.8±5.7[c] (60.7±23.6)	41.8±7.6 (58.1±27.0)	41.5±6.7 (63.1±26.3)	39.3±6.7 (58.7±28.5)
U13	Standing Height (cm)	158.9±8.7[c] (54.0±30.2)	157.3±8.8 (51.5±30.7)	155.9±8.2 (54.4±28.6)	153.5±8.4 (56.7±25.8)
	Body mass (kg)	47.8±8.4[c] (55.2±28.0)	46.9±8.2 (55.9±28.1)	46.2±7.2 (60.2±25.0)	43.0±6.0 (55.6±22.7)
U14	Standing Height (cm)	167.5±8.2[c] (58.9±26.6)	166.2±8.2[e] (59.9±28.5)	167.7±8.8[f] (70.0±26.0)[f]	160.3±7.0 (52.0±25.7)
	Body mass (kg)	56.1±9.6[c] (61.3±25.7)[b]	55.3±8.0[e] (64.1±23.7)	57.1±9.7[f] (72.9±23.9)	49.7±7.3 (57.6±23.0)
U15	Standing Height (cm)	172.9±7.7[c] (58.2±28.3)	172.8±6.7[e] (62.9±26.2)	171.7±8.4 (62.4±27.6)	167.5±9.0 (54.2±31.0)
	Body mass (kg)	63.2±8.9 (65.3±25.7)	63.3±8.2 (70.1±24.3)	60.9±10.4 (65.0±26.0)	58.7±10.4 (63.2±28.6)
U16	Standing Height (cm)	176.0±5.8 (57.5±24.6)	177.4±5.8 (65.3±21.1)	174.4±7.1 (56.6±27.4)	175.0±5.5 (63.7±23.4)
	Body mass (kg)	67.0±7.0 (65.8±20.7)	68.9±8.0 (71.7±17.5)	65.9±9.9 (65.3±25.0)	66.5±7.0 (73.2±17.8)
U17	Standing Height (cm)	178.5±6.9 (58.7±27.5)	177.1±6.4 (54.5±28.3)	179.1±7.3 (64.8±27.8)	175.5±4.5 (51.1±20.5)
	Body mass (kg)	70.9±7.7 (66.9±21.9)	71.5±8.1 (69.6±24.5)	70.9±8.2 (70.1±24.5)	66.9±7.2 (59.7±20.4)
U18	Standing Height (cm)	179.8±5.9 (61.9±26.5)	178.9±5.3 (57.7±23.4)	179.7±6.4 (61.1±27.2)	176.1±4.6 (46.7±22.6)
	Body mass (kg)	74.6±7.2[c] (71.9±21.9)	71.8±6.7 (64.7±20.9)	73.8±7.1 (71.2±18.5)	69.7±5.4 (62.5±18.0)
U19	Standing Height (cm)	179.9±5.1 (62.5±24.1)	178.3±5.9 (54.7±27.9)	179.9±5.8 (63.0±26.8)	179.3±3.6 (60.8±19.3)
	Body mass (kg)	77.3±7.3 (75.2±20.7)	72.7±6.5 (63.6±20.4)	76.4±6.5 (74.9±19.3)	77.9±10.0 (75.1±27.5)

Significant differences between quarters of selection year based on one-way ANOVA and post hoc Tukey analysis within age groups.
[a]Significant difference Quarter 1 vs. Quarter 2 $p<0.05$
[b]Significant difference Quarter 1 vs. Quarter 3 $p<0.05$
[c]Significant difference Quarter 1 vs. Quarter 4 $p<0.05$
[d]Significant difference Quarter 2 vs. Quarter 3 $p<0.05$
[e]Significant difference Quarter 2 vs. Quarter 4 $p<0.05$

[f]Significant difference Quarter 3 vs. Quarter 4 p<0.05

Table 7.1.3. Differences in physical performance between quarters of selection year by age groups.

	U9	U10	U11	U12	U13	U14	U15	U16	U17	U18	U19
RJ (cm)		a,b							e		e
CMJ (cm)											
CMJA (cm)	b	b									c,e,f
10 m Sprint (s)											
20 m Sprint (s)						c	c,d,e				
Agility (s)				B							
$\dot{V}O_{2peak}$ (ml.kg^{-1}.min^{-1})											

Significant differences between quarters of selection year based on one-way ANOVA and post hoc Tukey analysis within age groups.
[a]Significant difference Quarter 1 vs. Quarter 2 p<0.05
[b]Significant difference Quarter 1 vs. Quarter 3 p<0.05
[c]Significant difference Quarter 1 vs. Quarter 4 p<0.05
[d]Significant difference Quarter 2 vs. Quarter 3 p<0.05
[e]Significant difference Quarter 2 vs. Quarter 4 p<0.05
[f]Significant difference Quarter 3 vs. Quarter 4 p<0.05

Table 7.1.4. Season of birth of professional and non-professional players.

Season of birth	Playing Status	n	%
1st Quarter	Professional	69	35.0
	Non-Professional	357	47.2
2nd Quarter	Professional	62	31.5
	Non-Professional	202	26.7
3rd Quarter	Professional	44	22.3
	Non-Professional	126	16.6
4th Quarter	Professional	22	11.2
	Non-Professional	72	9.5

Key:
Professional players: participants over 18 years of age who became professional players.
Non-professional players: participants over 18 years of age who did not go on to become professional players.

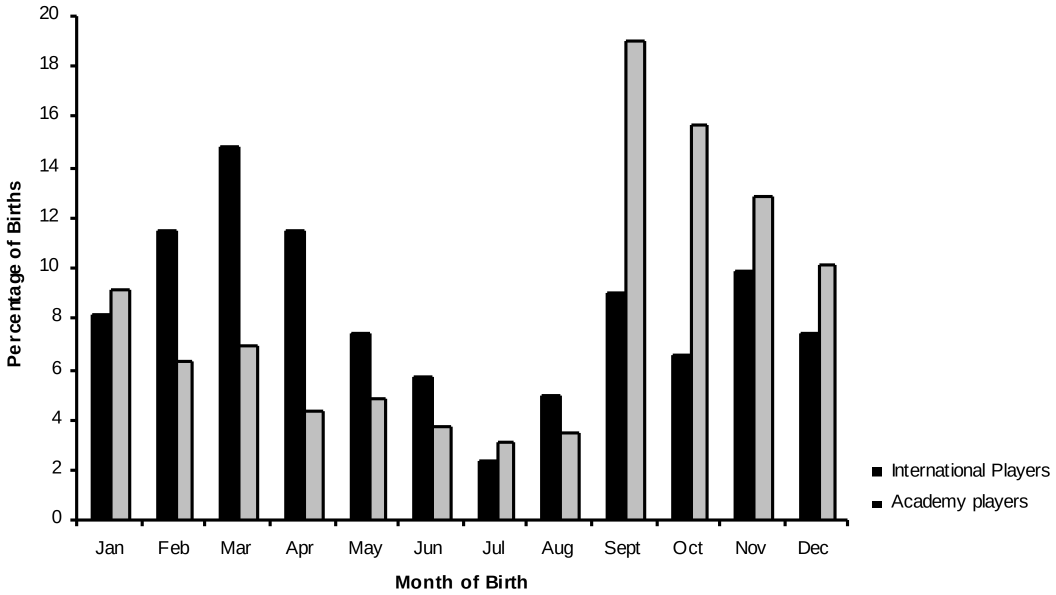


Figure 7.1.2. Month of birth of international and academy players.

7.1.4 DISCUSSION

The results of the present study demonstrate that a relative age effect is evident in English professional soccer academies, 72.3% of the players being born in the first 6 months of the selection year (Table 7.1.1). It was further shown, for the first time that a relative age effect was evident within each academy age group from U9s to U19s (Figure 7.1.1). The present study is the largest of its kind to date both in terms of the number and age range of the elite young players investigated. Consequently the current findings greatly expand upon those of previous studies in soccer (Dudink, 1994; Brewer et al., 1992; Brewer et al., 1995; Helsen et al., 1998; Musch and Hay, 1999; Helsen et al., 2000; Simmons and Paull, 2001; Jimenez and Pain, 2008; Carling et al., 2009; Williams, 2009), ice hockey (Boucher and Mutimer, 1994), baseball (Thompson et al., 1991) and tennis (Edgar and O'Donoghue, 2005).

Previous studies have attributed the relative age effect to physical advantages of relatively older players, although no anthropometric and performance data was collected to investigate if this was indeed the case (Brewer et al., 1992; Helsen et al., 2000). It has been suggested that in a sport like soccer, where advanced physical development is advantageous, the youngest players are at a considerable disadvantage (Helsen et al., 1998). Helsen and colleagues (1998) state that many children may be overlooked simply because they are born too late in the selection year and, by consequence, are physically less impressive. It is further surmised that 'talent' may be largely explained by physical precocity associated with a relative age advantage (Helsen et al., 1998). The physical attribute argument put forward by Helsen and colleagues (1998) was based purely on the observation of significant differences in height and body mass between different playing levels of youth players in Belgium, with those competing at the higher level being taller and heavier.

Some significant differences were evident in terms of the anthropometric characteristics of players born in different quarters of the selection year in the current study (Table 7.1.2). Those players born in the early part of the selection year were taller (U10, U11, U13, U14, U15) and heavier (U10, U12, U13, U14, U18) (Table 7.1.2). The fact that those born in the early part of the selection year were not significantly taller and heavier in all age groups suggests that anthropometric characteristics are not the sole explanation for the observed relative age effect. However, it is interesting to note that the significant differences in height and body mass were more evident in the younger age groups (U10-U15). This observation would support a suggestion made by Helsen and colleagues (2000) that the early age at which soccer begins high levels of competition compared to other youth sports compounds the relative age affect. In relation to this it had previously been argued that being selected at an early age increases an individual's chance of selection in later years by the processes of recognition, advanced training and experience in more advanced competition (Dudink, 1994).

The physical attribute explanation for the relative age effect is supported by the anthropometric characteristics of the players in the present study (Table 7.1.2). For example, the average 10 year old player born in the 1st Quarter of the selection had a standing height of 141.6 cm and body mass of 35.1 kg. This compared to the average 10 year old player born in the 4th Quarter of the selection year whose standing height was 134.5 cm and body mass was 31.1 kg. Clearly, a standing height and body mass advantage of 7.1 cm (5.0%) and 4.0 kg (11.4%) at this age will give those players born at the start of the selection year a greater physical presence in respect to their younger peers who are smaller and lighter. With all the evidence of more systematic training and selection influencing the anthropometric profiles of elite players (Reilly and Gilbourne, 2003), younger players who are more physically advanced within their respective age group squads are more likely to stand out to selectors. The influence of standing height was further noticeable when playing positions were analysed in the present study with 52.9% of centre backs born in the 1st Quarter whereas only 43.1% of full backs were born in the 1st Quarter. This finding underlines the influence of stature in the selection process, particularly in relation to certain playing positions. Taller stature can almost be perceived as being a pre-requisite for a centre back at the elite level.

Although a relative age effect was apparent in all age groups studied (U9-U19), a reduction in its severity was evident in the U18 and U19 age groups (Figure 7.1.1). Other researchers have noted a reduction in the relative age effect with increasing age in Belgian (Vaeyens et al., 2005) and Spanish players (Jimenez and Pain, 2008). Jimenez and Pain (2008) concluded that once physical development is completed, intrinsic advantages for early-borns are eliminated, allowing players who have been previously overlooked in the early selection process a later chance to succeed at the elite level. Such conclusions are supported by the finding in the present study that the majority of the significant differences in standing height and body mass between players born in different quarters of the selection year were evident below the U16 age group (Table 7.1.2). These findings would suggest that those involved in the selection process need to be acutely aware of such physical disparities between players born at different ends of the selection year especially when selecting players for the younger age group teams. The importance of this is highlighted by the suggestion that experiences and habits formed through training and practice at an early age determine future excellence (Howe et al., 1998).

The present results indicate only some significant differences in the physical performance (RJ; CMJA; 20 m speed; agility) of players born in different quarters of the selection year (Table 7.1.3). Recently a study of elite French academy players found no significant differences in fitness characteristics to exist between players born in different quarters of the selection year (Carling et al., 2009). Although Carling and colleagues (2009) observed a trend for players born in the 1st Quarter to outperform their peers born in the later quarters they concluded that the relative age of the player may not always be linked to a significant advantage in physical performance. However, when interpreting the findings of Carling and colleagues (2009) it should be noted that the study was limited to 160 players in the U14 age group. Previously it has been suggested that the superior physical size enjoyed by those born in the early part of the selection years is translated into an advantage in terms of physical performance (strength, speed and power) (Helsen et al., 1998). However, the current data relating to physical performance do not provide clear support of such a suggestion (Table 7.1.3). The present findings generally suggest that those players born late in the selection year are able to produce a level of physical performance (RJ; CMJ; CMJA; 10 m speed; 20 m speed; agility; $\dot{V}O_{2peak}$) that is similar to comparatively older players born earlier in the selection year. This may imply that selected players born later in the selection year are those who demonstrate a favourable level of physical performance in comparison to their older peers. It follows therefore that fewer 'younger' players are able to physically perform at such a level resulting in the relative age effect observed (Table 7.1.1).

The relative age effect was observed to be greater in those players who were not successful in gaining professional contracts in comparison to those who gained professional contracts (Table 7.1.4). This finding supports the suggestion that the advantages afforded to comparatively older more mature players may lead them to put less emphasis on the development of technical and tactical skills required at the elite level (Jiminez and Pain, 2008). It may therefore be the case that when the time comes relating to decisions on players in terms of professional contracts, those born early in the selection year no longer have the advantages provided by the relative age effect. Consequently, more of the comparatively younger players who developed the skills required at the elite level are offered professional contracts.

A shift in the skewed birth date distribution of international players compared with academy players was clearly evident in the present study (Figure 7.1.2). This shift can be attributed to the international players UEFA January 1st start date as opposed to the English Academy players start date of September 1st. This finding provides further evidence to support previous observations that the cut-off date is indeed a major and possibly causal factor underlying the relative age effect (Musch and Hay, 1999; Vaeyens et al., 2005). Musch and Hay (1999) found a shifted peak in the birth date distribution of Australian soccer professionals paralleling a corresponding change in the cut-off date in Australian soccer in 1989.

The present study demonstrated the existence of a relative age effect in 2,252 English Academy soccer players' and for the first time showed that this relative age effect existed in every age group from U9s through to U19s. The relatively early age which English Academy players start (U9s) may compound the relative age effect given the physical advantage (standing height and body mass) of those born early in the selection year in the younger age groups. Clearly, coaches and those involved in the process of talent identification need to be aware of the initial physical advantages afforded to those born early in the selection year. However, whilst there is a cut-off date in English Academy soccer one would suggest that the relative age effect will always exist.

7.1.4.1 Practical applications

This study illustrates to the practitioner the extent of relative age effect in English Academy soccer. Providing practitioners who work with elite young players with a knowledge and understanding of the relative age effect might help them to formulate more realistic physical performance expectations of individual players in relation to their relative age. Furthermore, an appreciation of a players' relative age is an important consideration within the talent identification process.

7.2 SEXUAL MATURITY AND ITS EFFECT ON ANTHROPOMETRIC AND PHYSICAL PERFORMANCE CHARACTERISTICS OF ELITE CHILD AND ADOLESCENT SOCCER PLAYERS

7.2.1 INTRODUCTION

Coaches in the highly competitive environment of elite soccer continue to search for the most effective methods of identifying and developing gifted young players (Stratton et al., 2005). In relation to this youth academies have been described as being vital for the long-term development of elite young players (le Gall et al., 2010). Much of the scientific research in youth soccer has been descriptive, documenting the anthropometric and physiological characteristics of young players (Jankovic et al., 1993; Franks et al., 2002; Gil et al., 2007). Other studies have been comparative, for example, comparing elite and non-elite players of the same chronological age (Hansen et al., 1999) and professional versus youth players (Rosch et al., 2000). However, few studies involving elite young players have considered the influence of maturation in relation to anthropometric and physical performance characteristics (Malina et al., 2004).

The most widely used indicators of biological maturation include skeletal, somatic and sexual maturation. The best maturational index is considered to be the assessment of skeletal age, although this measure of maturation is expensive, requiring specialist equipment and interpretation and involves the safety issue of exposure to radiation (Sherar, Baxter-Jones and Mirwald, 2004). Somatic methods of maturation assessment, for example age at peak height velocity (PHV) involves a series of measurements over the years surrounding the occurrence of PHV and therefore cannot be interpreted from a one-off measurement. Sherar, Baxter-Jones and Mirwald (2004) have suggested that the assessment of secondary sexual characteristics is the method of choice for many researchers because it is relatively inexpensive, has no safety issues and requires only one assessment. The methodology for the determination of sexual maturity whereby individuals are classified into one of five stages has previously been described by Tanner (1962). The determination of sexual maturity was traditionally obtained by direct visual observation, however, to reduce the ethical concerns most researchers now request that subjects rate their own sexual development, a method which has been shown to be both accurate and reliable (Petersen et al., 1988).

For boys from the general population the changes that occur in height, body mass and functional capacities such as muscle strength and power and aerobic power, during puberty have been described in detail (Malina, Bouchard and Bar-Or, 2004). Boys who are advanced in terms of sexual and skeletal maturity have been shown to perform better in tests of strength, power and speed in comparison to boys who are later in sexual and skeletal maturity, despite being within the same chronological age group (Malina, Bouchard and Bar-Or, 2004). Therefore, within a given chronological age group some children may be advantaged or disadvantaged in terms of physical performance due to their maturity status, especially when comparing results to age specific norms (Beunen et al., 1997). It has also been documented that the differences in performance between early and late maturing boys are most apparent between 13 and 16 years of age (Malina, Bouchard and Bar-Or, 2004).

However, information relating to maturity status and physical performance for elite young soccer players is very limited. Some researchers have suggested that adolescent boys who are advanced in terms of biological maturity tend to be more successful in soccer (Cacciari et al., 1990; Malina et al., 2000). Other studies of young soccer players have found that aerobic power increased with age and stage of puberty (Baxter-Jones et al., 1993; Jones and Helms, 1993). It has also been suggested that biological maturity status significantly influences the functional capacity of adolescent soccer players (Malina et al., 2004). However, no study has examined the influence of maturity status on a series of physical performance variables in young elite soccer players across a wide range of ages.

The aim of the present study was to investigate the influence of sexual maturity status on the physical performance of elite young players in professional English soccer academies and to test the hypothesis that players advanced in biological maturity would demonstrate a better level of physical performance.

7.2.2 METHODS

7.2.2.1 Participants

A total of 382 elite child and adolescent soccer players (age 13.6 ± 2.8 years; height 159.2 ± 16.2 cm; body mass 51.4 ± 15.9 kg) participated in this study. All the subjects were registered at one of two professional soccer club academies in England.

Estimated peak oxygen uptake ($\dot{V}O_{2peak}$) was measured in 115 subjects using the MSFT (Ramsbottom et al., 1988). A detailed description of the MSFT protocol can be found in section 3.4.5.

7.2.2.2 Measurement of sexual maturity

The procedures were carefully explained to the players by a same-sex researcher. Each player was asked to observe, in private, Tanner's photographs of the stages of secondary sex characteristics based on five stages of pubic hair development (Tanner, 1962). The subjects were asked to carefully view the pictures and make an informed decision about which stage most reflected their current status. Assurance of confidentiality and anonymity of subject information was stressed. A detailed description of this procedure can be found in section 3.3.3.9.

7.2.2.3 Procedures

A detailed description of the procedures and physical performance testing protocol can be found in sections 3.3 and 3.4.

7.2.2.4 Statistical analysis

Data were analysed using SPSS (Version 16.0, Chicago, Illinois, USA). Descriptive statistics were calculated. Independent *t* tests and one-way analysis of variance (ANOVA) were used to investigate differences in anthropometric and physical performance variables between the different sexual maturity groups. When a significant sexual maturity group effect was found a Tukey post hoc test was used to test differences among means. The ANCOVA statistical procedure was applied to the data to remove the influence of increasing standing height and body mass. Statistical significance was accepted at the 95% confidence level ($p<0.05$). Values are reported as mean (±SD).

7.2.3 RESULTS

7.2.3.1 Stages of Sexual Maturity

7.2.3.1.1 Anthropometric and physical performance characteristics

Descriptive statistics of the subjects are shown in Table 7.2.1. The chronological age range for players within each stage of sexual maturation was quite large, for example players in the first stage of sexual maturity ranged from 8.7 to 13.1 years of age (Table 7.2.1). A significant increase in both standing height and body mass was evident with each advance in stage of sexual maturation ($p<0.05$; Table 7.2.1). Similarly, significant increases in all physical performance measures were observed as the stage of sexual maturation progressed, for example CMJA performance increased by 20.3% between stages 1 and 3 ($p<0.05$; Table 7.2.1).

The ANCOVA statistical procedure was applied to the data to remove the influence of increasing standing height and body mass that accompanies increasing sexual maturity. Following this the only significant difference between the physical performance of players at different maturity stages was in the 20 m sprint test with players at a later Tanner stage being faster.

Table 7.2.1. Anthropometric and physical performance characteristics of players by stage of sexual maturity (mean±SD).

	Tanner Stage of Pubic Hair Development				
	1	2	3	4	5
n	43	81	72	79	107
Age (years)	10.0±1.1[b,c,d,e]	11.1±1.2[a,c,d,e]	12.6±1.4[a,b,d,e]	14.8±1.5[a,b,c,e]	16.6±1.7[a,b,c,d]
Age range (years)	8.7 – 13.1	9.0 – 14.5	9.5 – 15.8	12.3 – 18.3	13.1 – 19.5
Standing Height (cm)	137.8±6.6[b,c,d,e]	144.9±8.6[a,c,d,e]	153.4±9.4[a,b,d,e]	167.6±8.8[a,b,c,e]	176.2±6.9[a,b,c,d]
Body mass (kg)	33.1±5.2[b,c,d,e]	37.7±6.6[a,c,d,e]	43.9±7.7[a,b,d,e]	58.2±10.8[a,b,c,e]	69.2±8.6[a,b,c,d]
Body mass Index	17.3±1.7[c,d,e]	17.8±1.5[d,e]	18.5±1.9[a,d,e]	20.5±2.3[a,b,c,e]	22.2±1.8[a,b,c,d]
Reciprocal ponderal index	43.1±1.3	43.3±1.1	43.7±1.6[e]	43.5±1.4	43.0±1.1[c]
Ectomorphy	3.0±0.9	3.2±0.8	3.4±1.2[e]	3.2±1.0	2.9±0.8[c]
RJ (cm)	26.6±3.6[c,d,e]	27.7±4.5[c,d,e]	31.3±5.0[a,b,d,e]	35.8±5.2 [a,b,c,e]	39.5±5.0[a,b,c,d]
CMJ (cm)	26.4±4.0[c,d,e]	28.3±4.4[c,d,e]	31.6±5.2[a,b,d,e]	36.5±5.6[a,b,c,e]	40.4±5.4[a,b,c,d]
CMJA (cm)	30.1±5.0[c,d,e]	32.3±4.5[c,d,e]	36.2±6.0[a,b,d,e]	41.6±6.3[a,b,c,e]	45.7±6.4[a,b,c,d]
10 m Sprint (s)	2.04±0.10[b,c,d,e]	1.98±0.10[a,c,d,e]	1.91±0.08[a,b,d,e]	1.80±0.09[a,b,c,e]	1.76±0.08[a,b,c,d]
20 m Sprint (s)	3.68±0.19[b,c,d,e]	3.57±0.19[a,c,d,e]	3.41±0.18[a,b,d,e]	3.18±0.17[a,b,c,e]	3.05±0.15[a,b,c,d]
Agility (s)	4.92±0.30[b,c,d,e]	4.75±0.29[a,c,d,e]	4.53±0.24[a,b,d,e]	4.30±0.25[a,b,c]	4.20±0.22[a,b,c]
$\dot{V}O_{2peak}$ ($ml.kg^{-1}.bw^{-1}$)	41.2±5.6[c,d,e]	45.0±5.1[c,d,e]	50.8±4.9[a,b,d,e]	55.0±4.9[a,b,c]	58.2±6.2[a,b,c]

Significant differences between stage of pubic hair development based on one-way ANOVA and post hoc Tukey analysis.
[a]Significantly different to stage 1 p<0.05
[b]Significantly different to stage 2 p<0.05
[c]Significantly different to stage 3 p<0.05
[d]Significantly different to stage 4 p<0.05
[e]Significantly different to stage 5 p<0.05

7.2.3.1.2 Ethnic group characteristics

A general trend was observed whereby the average age of Black African players in each stage of pubic hair development was younger than that of the White and Black Caribbean players (Figure 7.2.1). For example, the average age of the players in stage 2 of pubic hair development was 6 months younger in the Black African players compared to the White players (10.5±0.5 vs. 11.1±1.2 years). Although these ethnic differences in average age were apparent in each stage of pubic hair development none were found to be significant.

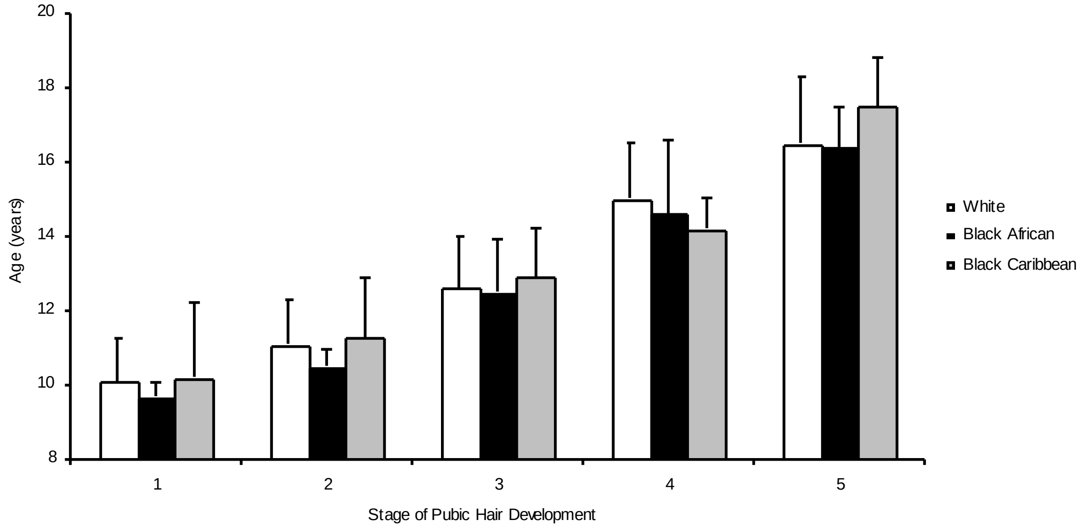


Figure 7.2.1. Chronological age of players by ethnic group and stage of pubic hair development (mean±SD).

7.2.3.2 Stages of sexual maturity by age group

7.2.3.2.1 Sexual maturity characteristics of the whole group

Players in all five stages of pubic hair development were evident in this sample of U9 to U19 players (Table 7.2.5). The majority of the players assessed across all age groups together were in stage 4 (20.6%) and stage 5 (28.2%), whilst the fewest were in stage 1 (11.2%) (Table 7.2.5). With the exception of the U17, U18 and U19 age groups a large range in stage of pubic hair development was found (Table 7.2.5). For example, players in the U12, U13 and U14 age groups were spread across four different stages of pubic hair development (Table 7.2.5).

Table 7.2.2. Sexual maturity characteristics of players by age group.

Age Group	Stage of pubic hair development (n)					Totals
	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	
U9	23	8	1	0	0	32
U10	8	24	5	0	0	37
U11	6	25	10	0	0	41
U12	5	15	23	4	0	47
U13	1	6	16	16	0	39
U14	0	3	15	25	9	52
U15	0	0	1	7	22	30
U16	0	0	1	16	18	35
U17	0	0	0	8	24	32
U18	0	0	0	3	22	25
U19	0	0	0	0	12	12
Total (n)	43	81	72	79	107	382
Total (%)	11.3	21.2	18.8	20.7	28.0	100.0

7.2.3.2.2 Anthropometric characteristics

Significant differences in the standing height of players based on their stage of pubic hair development were found in the U12 to U15 age groups (Figure 7.2.2). For example, a difference of 14 cm in standing height was apparent between U12 players in stage 1 (146.9±3.6 cm) and 4 (160.9±0.4 cm) of pubic hair development, respectively (Figure 7.2.2). Similarly, significant differences in the body mass of players based on their stage of pubic hair development were evident in the U12 to U16 age groups (Figure 7.2.3). For example, a difference of 12.1 kg in body mass was found to exist between U15 players in stage 4 (52.9±12.1 kg) and stage 5 (65.0±7.5 kg) of pubic hair development, respectively (Figure 7.2.3).

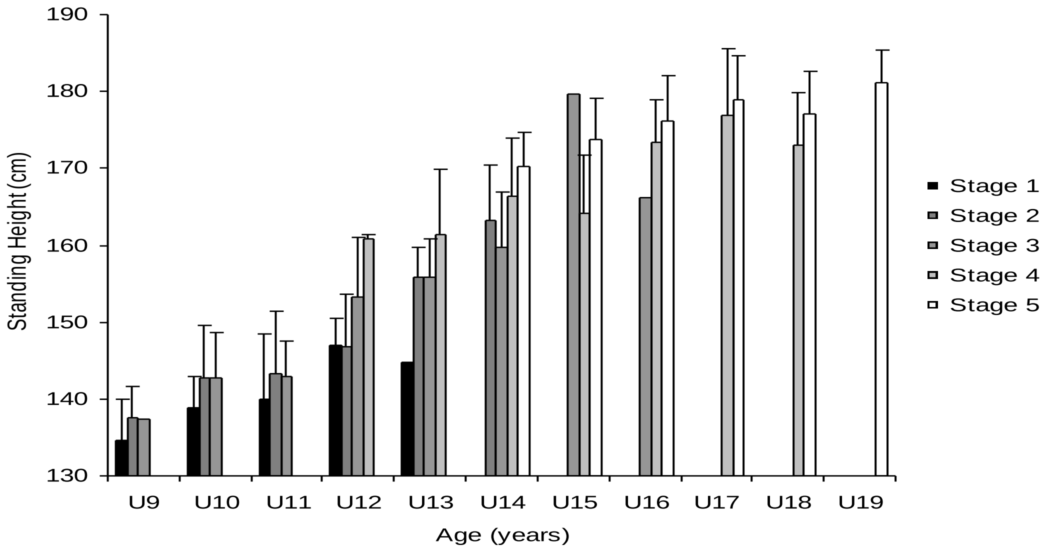


Figure 7.2.2. Standing height of players by age group and stage of pubic hair development (mean±SD).
Significant differences between stage of pubic hair development based on one-way ANOVA and post hoc Tukey analysis within age groups.
[b]Significantly different to stage 2 $p<0.05$
[c]Significantly different to stage 3 $p<0.05$
[d]Significantly different to stage 4 $p<0.05$

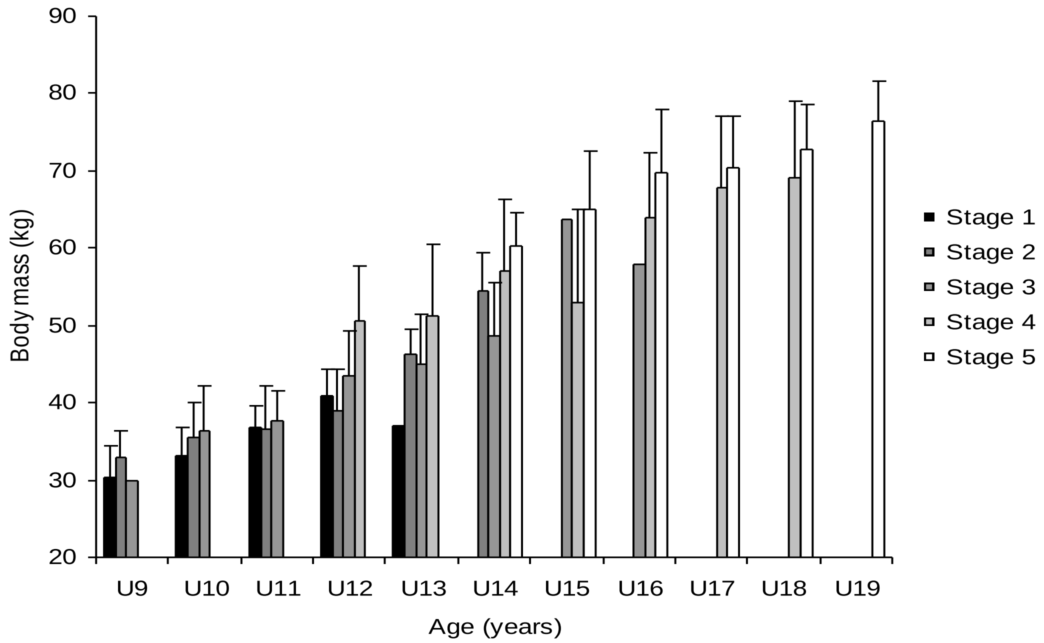


Figure 7.2.3. Body mass of players by age group and stage of pubic hair development (mean±SD).
Significant differences between stage of pubic hair development based on one-way ANOVA and post hoc Tukey analysis within age groups.
[b]Significantly different to stage 2 $p<0.05$
[c]Significantly different to stage 3 $p<0.05$
[d]Significantly different to stage 4 $p<0.05$

7.2.3.2.3 Physical performance characteristics

There was a trend for players who were more advanced in terms of stage of pubic hair development to have higher vertical jump scores than other players in their respective age groups who were less advanced (Figures 7.2.4; 7.2.5; 7.2.6). Although significant differences in vertical jump height for the more advanced players were only found in the U12, U13, U15 and U16 age groups (Figures 7.2.4; 7.2.5; 7.2.6). For example, mean RJ height of U12 players in stage 4 of pubic hair development was 12.2 cm higher than those in stage 1 (38.8±8.4 vs. 26.6±1.1 cm) (Figure 7.2.4).

A similar trend was observed in terms of sprint speed, where the players who were in the higher stages of pubic hair development in their respective age groups recorded the faster 10 m and 20 m sprint times (Figures 7.2.7; 7.2.8). The only significant differences in 10 m sprint speed were found in the U13 age group, whilst significant differences in 20 m sprint speed were evident in the U11, U12 and U13 age groups (Figures 7.2.7; 7.2.8). For example, the mean 20 m sprint time for U12 players in stage 4 of pubic hair development was 0.33 s faster than those in stage 1 (3.33±0.29 vs. 3.66±0.10 s) (Figure 7.2.8). No significant differences in agility test performance or estimated $\dot{V}O_{2peak}$ values were found to exist between players who were in different stages of pubic hair development within the same age group.

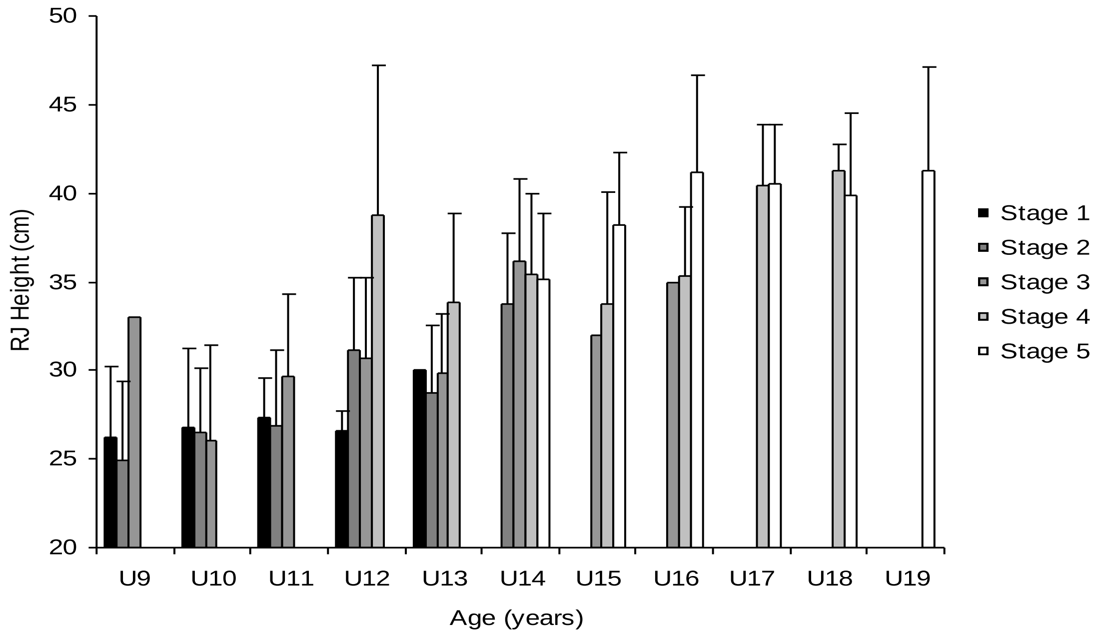


Figure 7.2.4. RJ height of players by age group and stage of pubic hair development (mean±SD).
Significant differences between stage of pubic hair development based on one-way ANOVA and post hoc Tukey analysis within age groups.
[d]Significantly different to stage 4 $p<0.05$

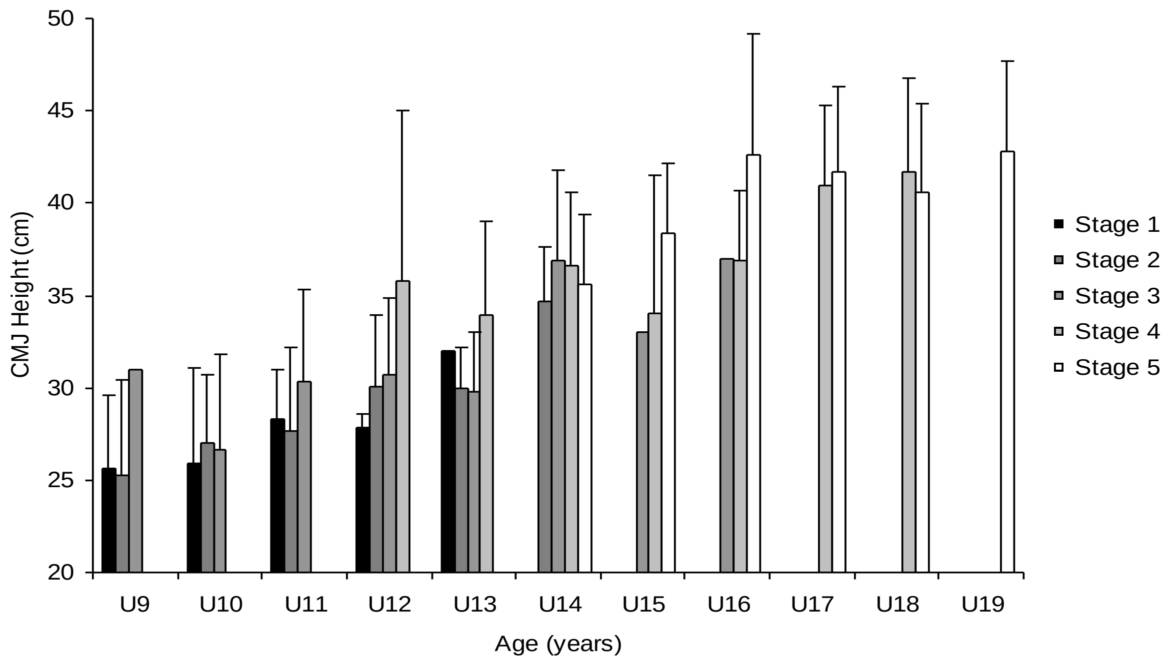


Figure 7.2.5. CMJ height of players by age group and stage of pubic hair development (mean±SD).
Significant differences between stage of pubic hair development based on one-way ANOVA and post hoc Tukey analysis within age groups.
[d]Significantly different to stage 4 $p<0.05$

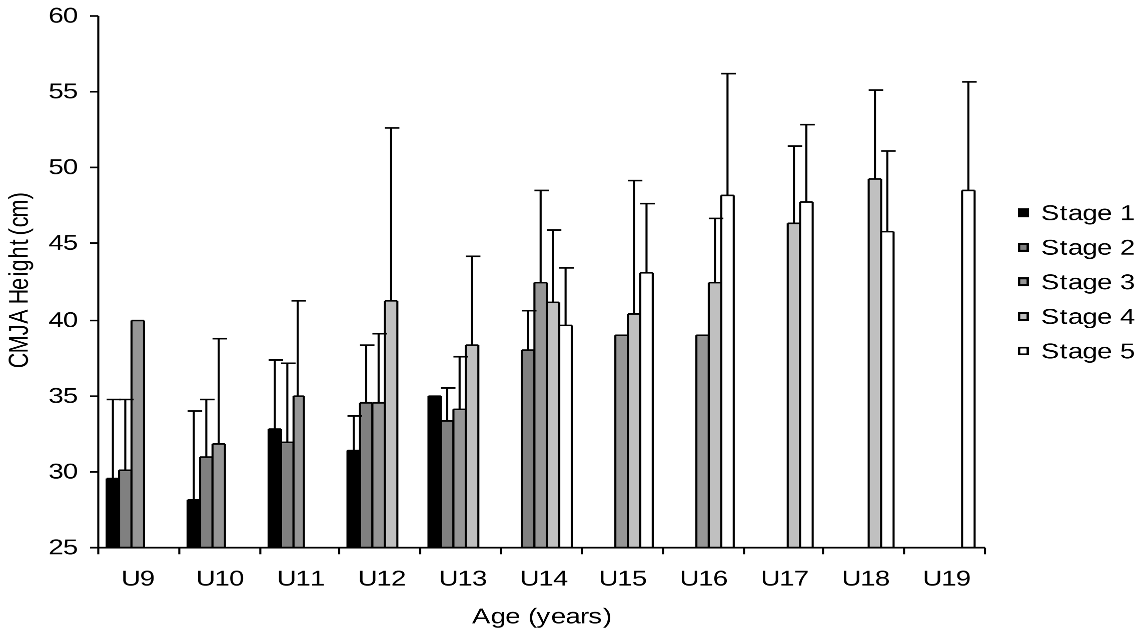


Figure 7.2.6. CMJA height of players by age group and stage of pubic hair development (mean±SD).
Significant differences between stage of pubic hair development based on one-way ANOVA and post hoc Tukey analysis within age groups.
[d]Significantly different to stage 4 $p<0.05$

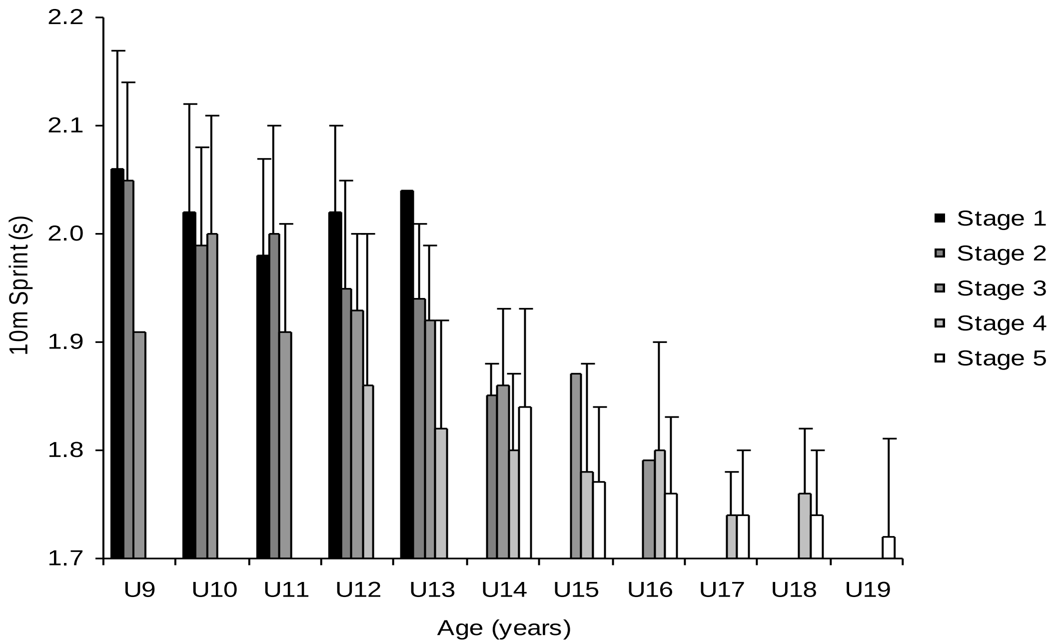


Figure 7.2.7. 10 m Sprint speed of players by age group and stage of pubic hair development (mean±SD).
Significant differences between stage of pubic hair development based on one-way ANOVA and post hoc Tukey analysis within age groups.
[d]Significantly different to stage 4 $p<0.05$

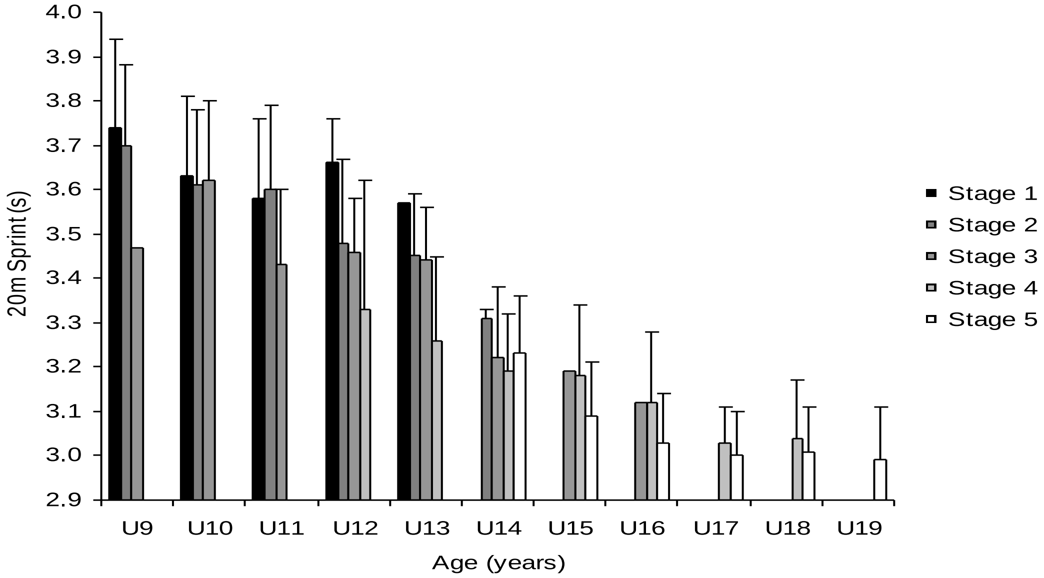


Figure 7.2.8. 20 m Sprint speed of players by age group and stage of pubic hair development (mean±SD).
Significant differences between stage of pubic hair development based on one-way ANOVA and post hoc Tukey analysis within age groups.
[c]Significantly different to stage 3 p<0.05
[d]Significantly different to stage 4 p<0.05

7.2.4 DISCUSSION

The present study was based on the self assessment method of sexual maturity using Tanner's stages of development (Tanner, 1962). Although biological maturity is most accurately assessed by measurement of skeletal age this is not always practical in large scale research such as the current study of 383 elite young players. In this type of study it has been suggested that the less intrusive measurement of Tanner's stages of development is more suited to use given the larger subject numbers (Jones, Hitchen and Stratton, 2000). Furthermore, self assessment of sexual maturation has been shown to be comparable to that of physician assessment (Saito, 1984).

The results of this study indicated a large chronological age range within each stage of pubic hair development for elite young players in professional English soccer academies. Players in the U12, U13 and U14 age groups were found to be spread across four different stages of pubic hair development. This finding of a large chronological age range of children within each stage of sexual maturation has been previously reported in a study of 313 school children, where for example boys in the fourth stage of sexual maturity ranged from 11.7 to 14.9 years (Jones, Hitchen and Stratton, 2000). Furthermore, studies of skeletal maturation have also found large chronological age ranges for a given skeletal age (Katmarzyk, Malina and Beunen, 1997). In light of these findings it would appear that because players in English soccer academies are grouped by chronological age irrespective of biological maturity some misclassification of players in relation to their biological maturity will occur. For this reason it has been suggested that differences in stage and rate of maturation disqualify chronological age as an accurate index of physical potential (Caine and Broekhoff, 1987).

The large chronological age range witnessed within each stage of biological maturation has been seen as a significant problem influencing sports participation and physical fitness ratings, with more mature children participating in sports requiring power and speed (Baxter-Jones, 1995). In the present study the stage of sexual maturity was found to be significantly positively correlated with improved physical performance on all tests. Similarly other studies have found significant improvements in physical fitness test performance with both stage of sexual maturity (Jones, Hitchen and Stratton, 2000; Malina et al., 2004) and skeletal age progression (Yang, 1989). One of the improvements in physical fitness test performance noted in the current study was the 20.3% increase in CMJA performance between stages 1 and 3 of pubic hair development. When one considers that players in the U9 to U11 age groups were found between stages 1 and 3 of pubic hair development the potential physical advantage afforded to the more mature players over their less mature age group peers is considerable. Differences in physical performance of this nature could have wider implications as it has been suggested that physical advantages or disadvantages as a result of maturity status can have a significant influence on intrinsic motivation to participate in physical activity (Whitehead and Corbin, 1991).

In the present study it was found that with each advance in stage of sexual maturation there was a significant increase in both the players standing height and body mass. It has been stated that body size, in particular standing height and body mass make a significant contribution to the variation in physical fitness performance throughout the stages of biological maturity (Katmarzyk, Malina and Beunen, 1997). Furthermore, Bouchard and colleagues (1976) found that when body size was accounted for no differences in physical performance between maturity groups were evident. Similarly, the current analysis revealed that when the combined influence of standing height and body mass was removed physical performance differences between sexual maturity stages were no longer evident, with the exception of the 20 m sprint test. However, other researchers have suggested that sexual maturity has a significant independent effect on physical fitness test performance (Jones, Hitchen and Stratton, 2000). This suggestion was based on the finding that differences between sexual maturity stages were evident in MSFT, CMJA and hand grip strength performance even when the combined influence of standing height and body mass was removed. Jones, Hitchen and Stratton (2000) suggested that increasing levels of androgens, especially testosterone, contributed significantly to the effect of sexual maturity on physical fitness test performance. However, despite the exception of the 20 m sprint test our results would appear to support the more widely held view that standing height and body mass are the most significant contributors to performance variation between stages of maturity (Beunen et al., 1981; Katmarzyk, Malina and Beunen, 1997).

The present study revealed that the more mature players in the U12 to U15 age groups were significantly taller, whilst the more mature players in the U12 to U16 age groups were significantly heavier. For example, the 12.1 kg difference in body mass found to exist between U15 players in stage 4 (52.9±12.1 kg) and stage 5 (65.0±7.5 kg) of pubic hair development is quite substantial. The potential impact of such differences could have a major impact on a players ability to compete physically within their respective age groups when one considers that body mass and stature are suggested to be the best predictors of muscle strength (Katmarzyk, Malina and Beunen, 1997) and strong contributors to performance variation (Beunen et al., 1981). Observations of this nature must be made apparent to youth coaches, particularly in the U12 to U15 age groups given the potential physical advantages afforded to the more mature players.

The current results also indicated a trend for players who were more advanced in terms of stage of pubic hair development to have better vertical jump (RJ; CMJ; CMJA) and sprint speed (10 m and 20 m) than other players in their respective age groups who were less advanced. Although it should be noted that significant differences in physical performance of this nature were only found in the U12, U13, U15 and U16 age groups for vertical jump performance and the U11, U12 and U13 age groups for sprint speed, with no significant differences in agility test performance or estimated $\dot{V}O_{2peak}$ values being found. In a previous comparison of 14 pre-pubertal (11 year old) and 14 post pubertal (16 year old) boys both RJ and CMJ performance were found to be lower, 16% and 15% respectively, in the pre-pubertal boys (Paasuke, Ereline and Gapeyeva, 2001). These differences were explained by an increase in the capacity for rapid neural activation of the extensor muscles of the lower extremities in post-pubertal boys compared with pre-pubertal boys (Paasuke, Ereline and Gapeyeva, 2001). It should be noted that some of the differences in vertical jump performance observed between players at different stages of maturity within the same age group in the present study are much greater than those observed by Paasuke, Ereline and Gapeyeva (2001). For example, mean RJ height of U12 players in stage 4 of pubic hair development was 31.4% higher than those in stage 1. Clearly, differences in performance of this nature will afford the more mature players within these age groups a huge physical advantage in game related actions which are a direct manifestation of strength, speed and power. Malina and colleagues (2004) suggested that variance in vertical jump and 30 m sprint performance in adolescent soccer players was a consequence of differences in body size and stage of maturity. In the present study the age groups in which significant differences in body size between players at different stages of maturity were similar to the age groups where significant differences in vertical jump and sprint performance were found. These current observations would appear to provide further support to the suggestion that variance in vertical jump and sprint performance is strongly related to differences in body size and stage of maturity.

The present study revealed a general although not significant trend whereby the average age of Black African players in each stage of pubic hair development was younger than that of the White and Black Caribbean players. For example, the average age of the players in stage 2 of pubic hair development was 6 months younger in the Black African players compared to the White players (10.5±0.5 vs. 11.1±1.2 years). This finding would appear to support the suggestion that the timing of sexual maturation in Black boys is earlier than in White boys (Sun et al., 2004).

Based on the current findings the noted trend of advanced maturity status in young Black African players could provide a physical advantage in terms of body size and strength which may be translated into better physical performance characteristics in comparison to the later maturing White and Black Caribbean players.

The results of this study highlight the large chronological age range within each stage of pubic hair development for elite young players in professional English soccer academies. It would appear that the positive influence that advanced maturity status has on physical performance characteristics of the players is mainly a product of the associated increase in standing height and body mass. The results clearly display the importance of taking into account the maturity status of players when assessing physical performance.

7.2.4.1 Practical applications

The present results highlight to practitioners the problems associated with using chronological age as an accurate index of physical performance potential. Those working with elite young players must take into account more than just chronological age when assessing performance given the large potential variation in maturity status of players within the same age group that has been highlighted in this study. The self assessment method of sexual maturity (Tanner, 1962) used in the current study is a less intrusive measurement of of Tanner's stages of development and therefore maybe more applicable for practitioners to use when dealing with large numbers of players as is the case in a professional English soccer academy.

CHAPTER 8

LONGITUDINAL DEVELOPMENT OF ANTHROPOMETRIC AND PHYSICAL PERFORMANCE CHARACTERISTICS IN ELITE CHILD AND ADOLESCENT SOCCER PLAYERS

8.1 INTRODUCTION

In chapter 6 cross-sectional data was used to analyse developmental changes in anthropometric and physical performance characteristics in elite child and adolescent soccer players. Changes in body size, physique and body composition associated with growth and maturation are important factors that affect physical function and motor performance (Malina, Bouchard and Bar-Or, 2004). In child and adolescent players developmental changes in physical performance, for example, vertical jump, sprint speed and agility will be affected by growth and maturation. To identify the contribution of growth on developmental changes in physical performance there is a need to collect data longitudinally. Few longitudinal studies have considered the influence of growth on physical performance in elite child and adolescent soccer players.

An appropriate method to analyse longitudinal growth data is some form of multilevel modelling process (Goldstein, 1995). It is suggested that when modelling growth data 'age' should be incorporated as additive polynomial terms, where any systematic change in the residual error can also be modelled simultaneously within the multilevel analysis (Goldstein, 1986). However, the use of additive models to explain differences in physical performance variables has been criticised (Nevill and Holder, 1995). Nevill and Holder (1995) argue that because physical performance variables such as strength are known to be proportional to but nonlinear with body mass, an additive polynomial model is unlikely to explain developmental changes over time satisfactorily. Based on these observations Nevill and Holder (1995) proposed an alternative multiplicative (proportional) model with allometric body size components to describe developmental changes in physical performance variables that should accommodate the nonlinear but proportional changes with body mass and overcome the heteroscedastic errors observed with such variables. To date, an appropriate statistical analysis of longitudinal data relating to elite young and adolescent soccer players has not been published.

In the present study on elite young and adolescent soccer players longitudinal measurements of anthropometric and physical performance variables were analysed using two multilevel model structures, the additive polynomial structure and the multiplicative allometric structure, respectively. The purpose of this study was therefore to use multilevel modelling to examine longitudinally the effects of age, standing height and body mass on physical performance characteristics of elite young and adolescent soccer players. The hypothesis to be tested was that the greatest changes in physical performance would occur at the time corresponding with the peak height or weight velocity.

8.2 METHODS

8.2.1 Participants

A total of 2,252 subjects (age 14.3±2.1 years; height 164.3±13.6 cm; body mass 55.2±14.2 kg) participated in this study. These subjects completed between 1 and 6 testing sessions during the 3 seasons in which the data collection took place (6088 data points).

8.2.2 Procedures

A detailed description of the procedures and physical performance testing protocol can be found in sections 3.3 and 3.4.

8.2.3 Statistical analysis

Data were analysed using MLwiN (Version 2.16, Bristol, U.K.). An additive polynomial multilevel model (Goldstein et al., 1994) was used to examine the longitudinal development of standing height and body mass in the academy players who were tested between September 2002 and July 2005. Age, age squared and age cubed (centred on age 13) were used as explanatory variables. All parameters were fixed, except the constant parameter, which was allowed to vary randomly at levels 1, 2 and 3 (repeated measurements, player and club respectively). The longitudinal development of performance characteristics (RJ; CMJ; CMJA; 10 m speed, 20 m speed and agility) was investigated using a multiplicative allometric model (Nevill et al., 1998). The development of a particular performance variable (which was log transformed for the analysis) was explained as a function of log transformed body mass, log transformed standing height, age and age squared. All parameters were fixed except the constant parameter, which was allowed to vary randomly at levels 1, 2 and 3 (repeated measurements, player and club respectively) and the age and age squared variables which were allowed to vary at level 2 (player). Values are reported as mean (±SD).

8.3 RESULTS

8.3.1 Anthropometric characteristics

Multilevel additive polynomial analysis of standing height suggests a thirteen year old player will average 158.1 cm in standing height, and that their rate of growth will average 6.5 $cm.yr^{-1}$ (Table 8.1). A peak increase in standing height velocity of 6.5 $cm.yr^{-1}$ was observed at 12.3 years (Figure 8.2).

Multilevel additive polynomial analysis suggests that the average body mass of a 13 year old player will be 48.3 kg, and that the typical rate of change in body mass is 5.7 kg per year (Table 8.2). A peak increase in body mass velocity of 5.8 $kg.yr^{-1}$ was observed at 13.8 years (Figure 8.4).

Table 8.1. Multilevel additive polynomial analysis of standing height (cm) in elite academy players.

Fixed Explanatory Variables	Parameter estimate (SE)
Constant	158.056 (0.267)**
Age (centred on age 13 years)	6.511 (0.043)**
Age squared (centred on age 13 years)	-0.099 (0.007)**
Age cubed (centred on age 13 years)	-0.071 (0.002)**
Random Variance	
Level1 (Club)	0.995 (0.468)**
Level 2 (Player)	44.974 (1.384)**
Level 3 (Repeated measurements)	2.656 (0.061)**
-2*loglikelihood (IGLS Deviance)	31552.531

**p<0.05

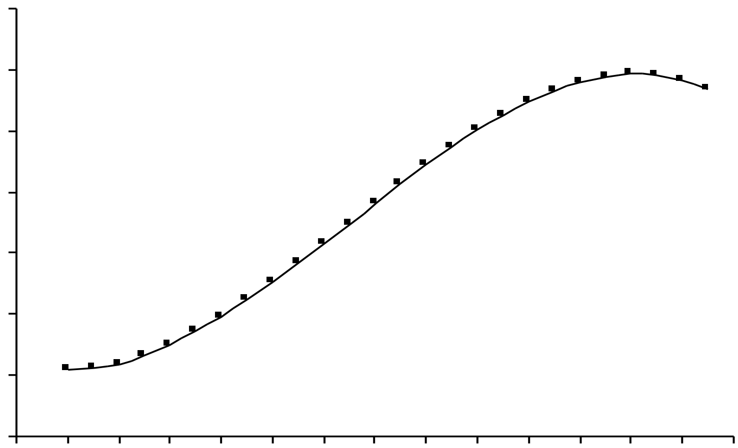


Figure 8.1. Standing height (cm) prediction in elite academy players.
Prediction equation:- Standing height (cm) = 158.056 + 6.511*age + -0.099*age^2 +-0.071*age^3.

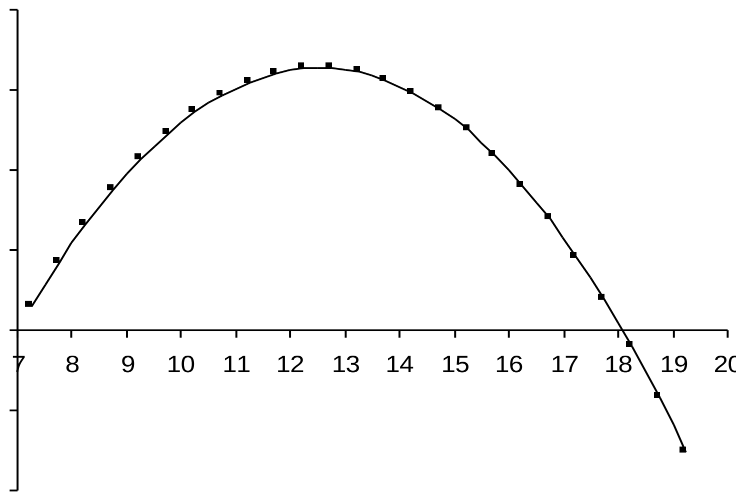


Figure 8.2. Standing height velocity (cm) in elite academy players.

Table 8.2. Multilevel additive polynomial analysis of body mass (kg) in elite academy players.

Fixed Explanatory Variables	Parameter estimate (SE)
Constant	48.333 (0.261)**
Age (centred on age 13 years)	5.720 (0.050)**
Age squared (centred on age 13 years)	0.121 (0.009)**
Age cubed (centred on age 13 years)	-0.063 (0.002)**
Random Variance	
Level1 (Club)	0.876 (0.437)
Level 2 (Player)	46.056 (1.437)**
Level 3 (Repeated measurements)	3.795 (0.087)**
-2*loglikelihood (IGLS Deviance)	32997.463

**p<0.05

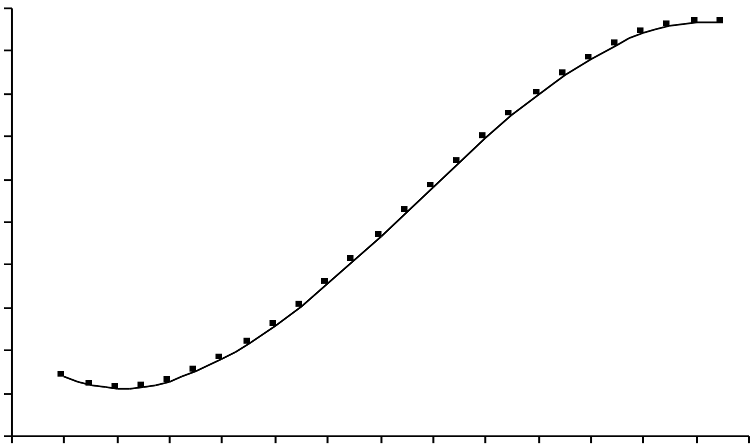


Figure 8.3. Body mass (kg) prediction in elite academy players.
Prediction equation:- Body mass (kg) = 48.333 + 5.720*age + 0.121*age^2 +-0.063*age^3.

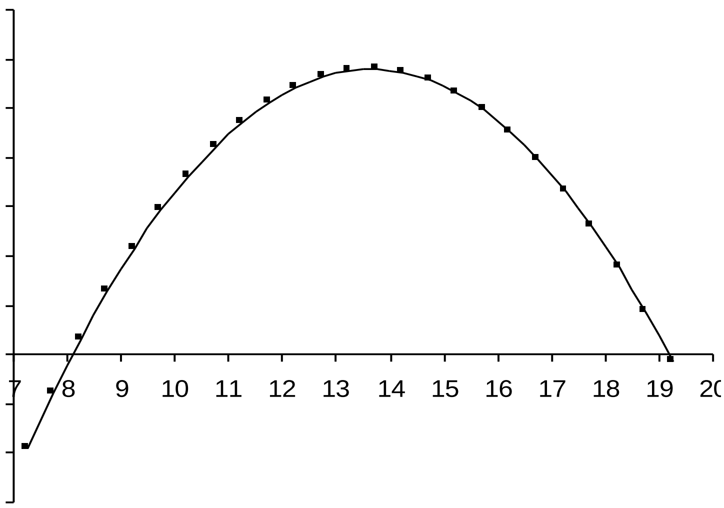


Figure 8.4. Body mass velocity (cm) in elite academy players.

8.3.2. Physical performance characteristics

Multilevel multiplicative allometric analysis of RJ, CMJ and CMJA height showed body mass, standing height and age to be significant explanatory variables (Tables 8.3, 8.4 and 8.5). Peak rate of change in RJ (1.86 $cm.yr^{-1}$), CMJ (2.00 $cm.yr^{-1}$) and CMJA (2.41 $cm.yr^{-1}$) height occurred at 13.3 years (Figures 8.6, 8.8 and 8.10).

Multilevel multiplicative allometric analysis of 10 m, 20 m and agility speed showed body mass, standing height and age to be significant explanatory variables (Tables 8.6, 8.7 and 8.8). Peak rate of change in 10 m (0.13 $m.s.yr^{-1}$), 20 m (0.17 $m.s.yr^{-1}$) and agility (0.15 $m.s.yr^{-1}$) speed occurred at 12.3 years for 10 m and 20 m speed and at 7.3 years for agility (Figures 8.12, 8.14 and 8.16).

Table 8.3 Multilevel multiplicative allometric analysis of RJ height (cm) in elite academy players.

Fixed Explanatory Variables	Parameter estimate (SE)
Constant	1.562 (0.338)**
Body mass (kg) (Log transformed)	0.046 (0.024)**
Standing height (cm) (Log transformed)	0.334 (0.079)**
Age (centred on age 13 years)	0.041 (0.002)**
Age squared (centred on age 13 years)	-0.001 (0.000)**
Random Variance	
Level1 (Club)	0.002 (0.001)**
Level 2 (Player)	0.013 (0.001)**
Level 3 (Repeated measurements)	0.005 (0.000)**
-2*loglikelihood (IGLS Deviance)	-10004.490

**p<0.05

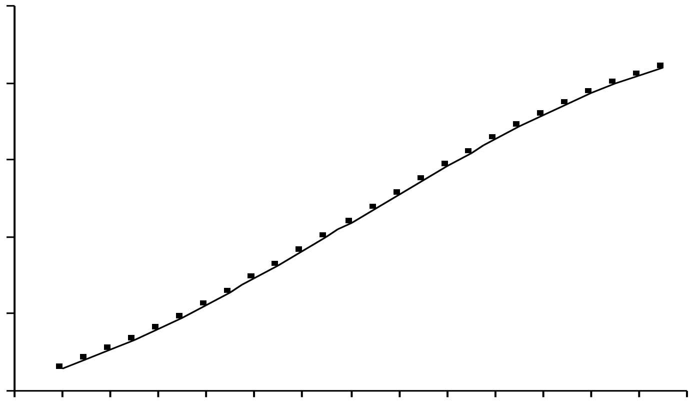


Figure 8.5. RJ height (cm) prediction in elite academy players.
Prediction equation:- RJ height (cm) = Body mass$^{0.046}$ * standing height$^{0.334}$ * exp(1.562 + (0.041*age) + (-0.001*age^2)).

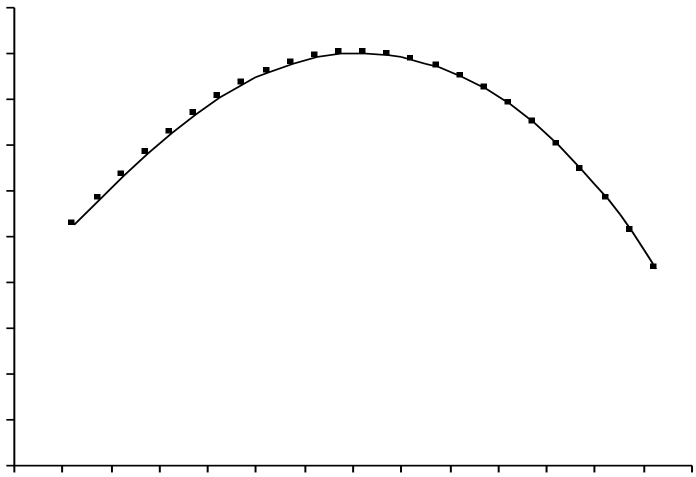


Figure 8.6. Rate of change in RJ height (cm) in elite academy players.

Table 8.4. Multilevel multiplicative allometric analysis of CMJ height (cm) in elite academy players.

Fixed Explanatory Variables	Parameter estimate (SE)
Constant	1.025 (0.341)**
Body mass (kg) (Log transformed)	0.036 (0.024)
Standing height (cm) (Log transformed)	0.450 (0.080)**
Age (centred on age 13 years)	0.041 (0.002)**
Age squared (centred on age 13 years)	-0.001 (0.000)**
Random Variance	
Level1 (Club)	0.002 (0.001)**
Level 2 (Player)	0.013 (0.001)**
Level 3 (Repeated measurements)	0.005 (0.000)**
-2*loglikelihood (IGLS Deviance)	-9884.048

**p<0.05

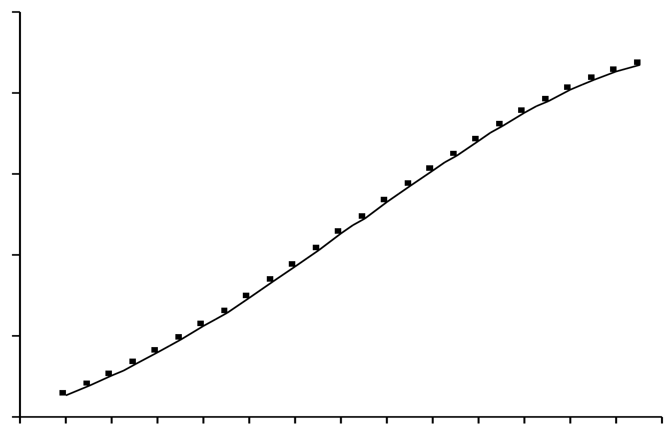


Figure 8.7. CMJ height (cm) prediction in elite academy players.
Prediction equation:- CMJ height (cm) = Body mass$^{0.036}$ * standing height$^{0.450}$ * exp(1.025 + (0.041*age) + (-0.001*age^2)).

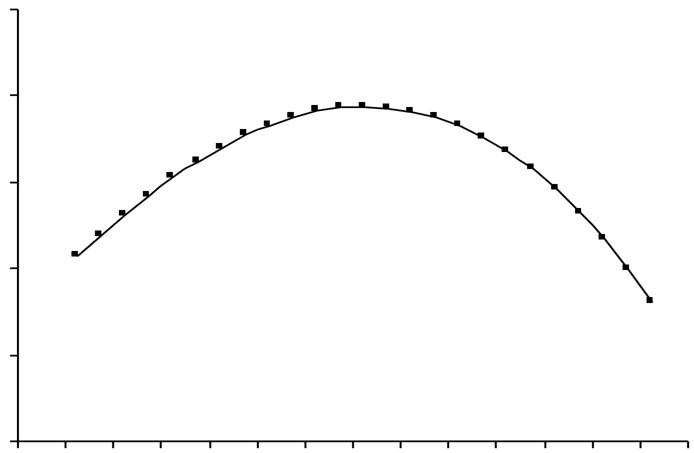


Figure 8.8. Rate of change in CMJ height (cm) in elite academy players.

Table 8.5. Multilevel multiplicative allometric analysis of CMJA (cm) in elite academy players.

Fixed Explanatory Variables	Parameter estimate (SE)
Constant	1.211 (0.335)**
Body mass (kg) (Log transformed)	0.050 (0.024)**
Standing height (cm) (Log transformed)	0.428 (0.079)**
Age (centred on age 13 years)	0.044 (0.002)**
Age squared (centred on age 13 years)	-0.001 (0.000)**
Random Variance	
Level1 (Club)	0.002 (0.001)**
Level 2 (Player)	0.013 (0.001)**
Level 3 (Repeated measurements)	0.005 (0.000)**
-2*loglikelihood (IGLS Deviance)	-10244.835

**p<0.05

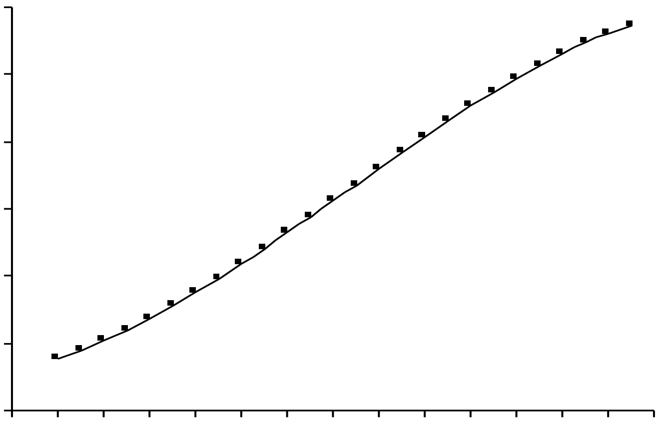


Figure 8.9. CMJA height (cm) prediction in elite academy players.
Prediction equation:- CMJA height (cm) = Body mass$^{0.050}$ * standing height$^{0.428}$ * exp(1.211 + (0.044*age) + (-0.001*age^2)).

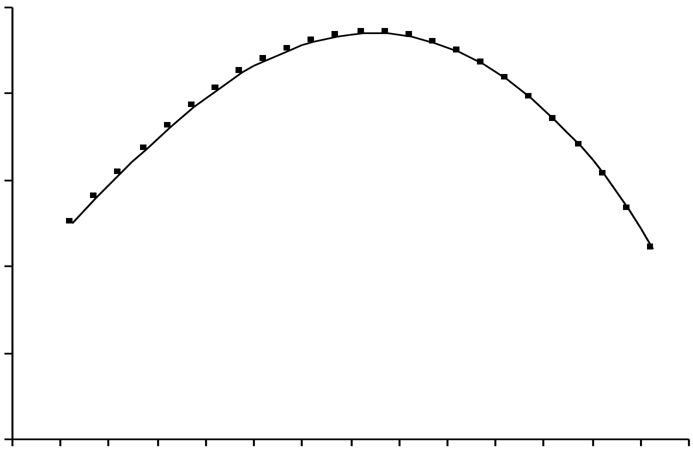


Figure 8.10. Rate of change in CMJA height (cm) in elite academy players.

Table 8.6. Multilevel multiplicative allometric analysis of 10 m speed (m.s^{-1}) in elite academy players.

Fixed Explanatory Variables	Parameter estimate (SE)
Constant	1.046 (0.123)**
Body mass (kg) (Log transformed)	0.024 (0.009)**
Standing height (cm) (Log transformed)	0.107 (0.029)**
Age (centred on age 13 years)	0.016 (0.0007)**
Age squared (centred on age 13 years)	-0.0002 (0.0001)**
Random Variance	
Level1 (Club)	0.0002 (0.00008)**
Level 2 (Player)	0.0011 (0.00006)**
Level 3 (Repeated measurements)	0.0011 (0.00002)**
-2*loglikelihood (IGLS Deviance)	-21266.969

**p<0.05

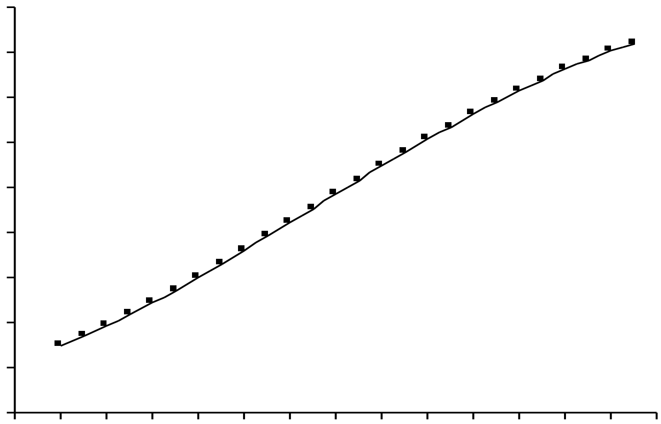


Figure 8.11. 10 m speed (m.s^{-1}) prediction in elite academy players.
Prediction equation:- 10 m speed (s) = Body mass$^{0.024}$ * standing height$^{0.107}$ * exp(1.046 + (0.016*age) + (-0.0002*age^2)).

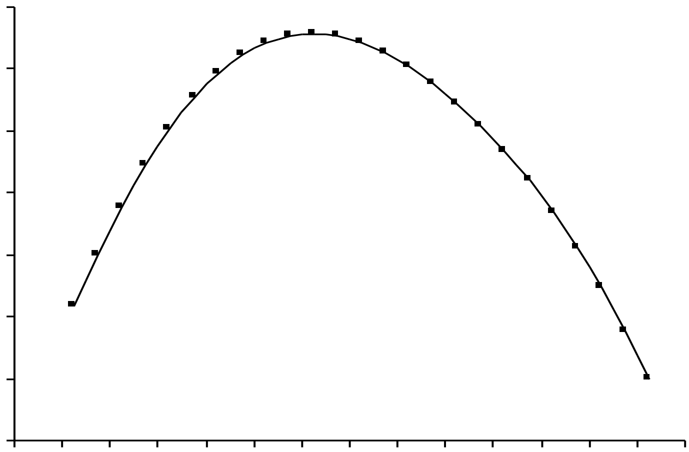


Figure 8.12. Rate of change in 10 m speed (m.s^{-1}) in elite academy players.

Table 8.7. Multilevel multiplicative allometric analysis of 20 m speed ($m.s^{-1}$) in elite academy players.

Fixed Explanatory Variables	Parameter estimate (SE)
Constant	0.907 (0.119)**
Body mass (kg) (Log transformed)	0.019 (0.008)**
Standing height (cm) (Log transformed)	0.161 (0.028)**
Age (centred on age 13 years)	0.019 (0.001)**
Age squared (centred on age 13 years)	-0.0003 (0.0001)**
Random Variance	
Level1 (Club)	0.0001 (0.0000)**
Level 2 (Player)	0.0013 (0.0001)**
Level 3 (Repeated measurements)	0.0009 (0.0000)**
-2*loglikelihood (IGLS Deviance)	-22105.672

**p<0.05

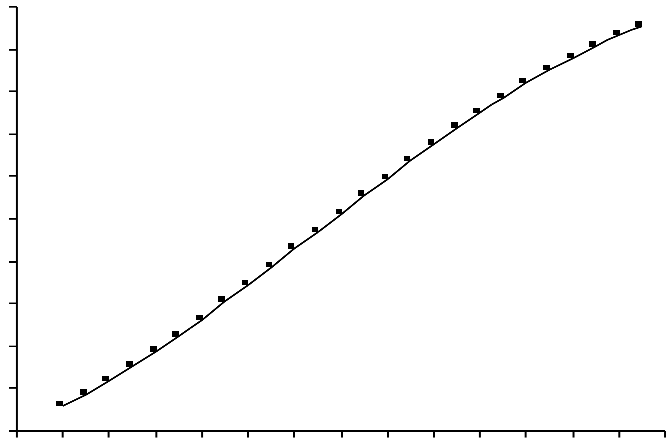


Figure 8.13. 20 m speed ($m.s^{-1}$) prediction in elite academy players.
Prediction equation:- 20 m speed (s) = Body mass$^{0.019}$ * standing height$^{0.161}$ * exp(0.907 + (0.019*age) + (-0.0003*age^2)).

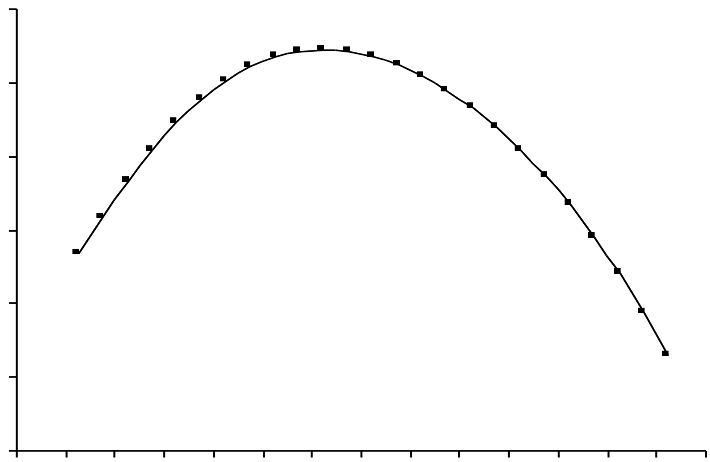


Figure 8.14. Rate of change in 20 m speed ($m.s^{-1}$) in elite academy players.

Table 8.8. Multilevel multiplicative allometric analysis of speed during the agility test ($m.s^{-1}$) in elite academy players.

Fixed Explanatory Variables	Parameter estimate (SE)
Constant	0.776 (0.141)**
Body mass (kg) (Log transformed)	-0.055 (0.010)**
Standing height (cm) (Log transformed)	0.190 (0.033)**
Age (centred on age 13 years)	0.024 (0.001)**
Age squared (centred on age 13 years)	-0.001 (0.000)**
Random Variance	
Level1 (Club)	0.001 (0.000)**
Level 2 (Player)	0.002 (0.000)**
Level 3 (Repeated measurements)	0.001 (0.000)**
-2*loglikelihood (IGLS Deviance)	-19444.350

**p<0.05

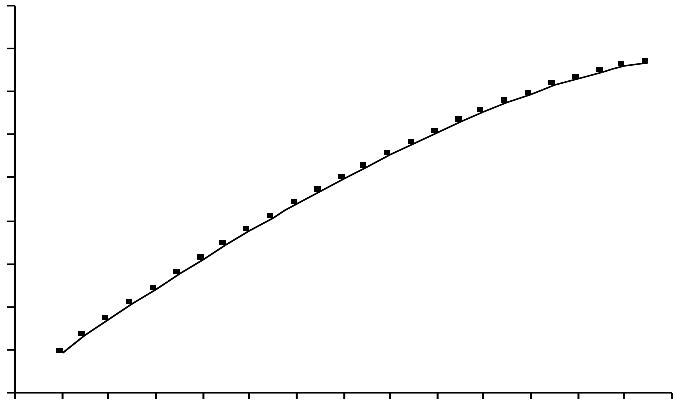


Figure 8.15. Agility test speed ($m.s^{-1}$) prediction in elite academy players.
Prediction equation:- Agility speed (s) = Body mass$^{-0.055}$ * standing height$^{0.190}$ * exp(0.776 + (0.024*age) + (-0.001*age^{2})).

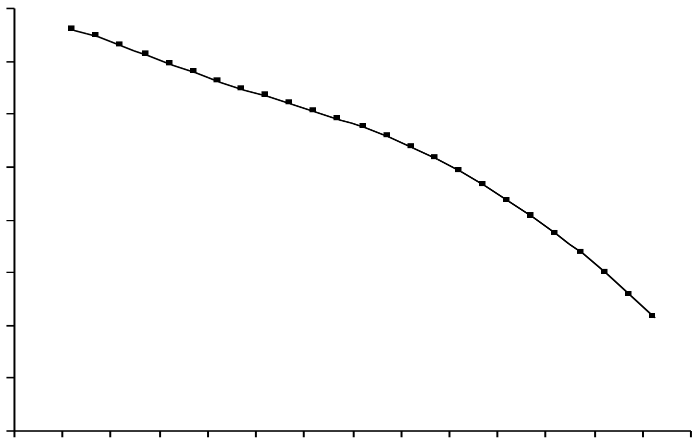


Figure 8.16. Rate of change in agility test speed ($m.s^{-1}$) in elite academy players.

8.4 DISCUSSION

The key finding of the present longitudinal study was that multilevel additive polynomial analysis of standing height and body mass in elite academy players suggests a peak increase in standing height (6.5 $cm.yr^{-1}$) and body mass (5.8 $kg.yr^{-1}$) velocity at 12.3 and 13.8 years, respectively. Multilevel multiplicative allometric analysis suggested that the peak rate of change in 10 m (0.13 $m.s.yr^{-1}$) and 20 m (0.17 $m.s.yr^{-1}$) speed occurred at the time of PHV (12.3 years), but that peak rate of change in RJ (1.86 $cm.yr^{-1}$), CMJ (2.00 $cm.yr^{-1}$) and CMJA (2.41 $cm.yr^{-1}$) height occurred at 13.3 years, a year after the reported PHV. However, the peak rate of change in agility (0.15 $cm.yr^{-1}$) was found to occur at 7.3 years, well in advance of PHV.

Longitudinal studies in which young soccer players are followed for several years from childhood through adolescence are very limited (Malina et al., 2000). The present study of 2252 elite academy players based on 6088 data points collected over the course of 3 seasons (2002-2003; 2003-2004; 2004-2005) is by far the largest longitudinal study of its kind to date. Smaller longitudinal studies of 32 Welsh (Bell, 1993) and 8 Danish (Froberg et al, 1991) youth soccer players estimated age at peak height velocity to be 14.2 $\pm$ 0.9 years. The cross-sectional analysis presented in Chapter 6.1 similarly suggested the mean age at PHV to be 13.7 years. However, in the present study the multilevel additive polynomial analysis of standing height suggests PHV to occur at the earlier age of 12.3 years. This is outside the range of estimated ages at peak height velocity for samples of European boys (13.8 – 14.2 years; Malina et al, 2004). The prediction of a slightly earlier onset of PHV in this group of elite young players may reflect the existence of a selection bias related to advanced maturity status, where taller and heavier players have an increased likelihood of selection, (Brewer, Balsom and Davis, 1995; Helsen et al., 2000). The current finding of PHV occurring at a relatively early age fits in with the existence of a relative age effect in the this group of elite players (Chapter 7.1) and further reflects the suggestion that the positive influence that advanced maturity status has on physical performance characteristics in these players is mainly a product of the associated increase in standing height and body mass (Chapter 7.2).

In the present study the PHV of 6.5 $cm.yr^{-1}$ is well below that reported in Chapter 6.1 (9.0 $cm.yr^{-1}$) from the cross-sectional analysis of the same group of elite players. This figure is also below the range of 8.2 to 10.3 $cm.yr^{-1}$ reported for European boys (Malina et al, 2004) and is less than the estimated PHV of 9.7 $cm.yr^{-1}$ reported for Flemish players (Philippaerts et al, 2006). These differences may reflect the different statistical approach in the respective studies, with a multilevel additive polynomial analysis of standing height being adopted in the current study.

The multilevel additive polynomial analysis of body mass revealed the peak weight velocity (PWV) at 13.8 years (5.8 $kg.yr^{-1}$) in this group of elite academy players, occurring 1.5 years after the reported PHV. This finding is in accordance with previous observations on the relative timing of PWV and PHV (Malina et al., 2000; Malina, Bouchard and Bar-Or, 2004).

The analysis of longitudinal physical performance data can be challenging to the researcher, especially the interpretation of data in relation to changes in body size and composition (Armstrong et al., 2000). Previously some researchers who have used multilevel modelling to explain developmental changes in physical performance have adopted an additive polynomial model (Baxter-Jones, Goldstein and Helms, 1993). However, it has been suggested that a limitation of the additive polynomial approach is that the fitted model is only valid within the range of observations collected (Nevill et al., 1998). It has been demonstrated that multiplicative allometric models provide more plausible solutions within and beyond the range of observations when considering experimental design effects and other problems associated with scaling for growth and maturation (Nevill and Holder, 1995). Furthermore, it has been suggested that as children grow, their leg volume increases in a greater proportion to their body mass (Nevill, 1994a). To accommodate the effect of a disproportionate increase in leg muscle on physical performance variables it has been suggested that standing height as well as body mass be included as a continuous covariate to explain developmental changes in physical performance (Nevill, 1994b). For these reasons, the multiplicative allometric model was used, within a multilevel structure to explain the developmental changes in physical performance in elite academy players in the present study.

The multilevel multiplicative allometric analysis of RJ, CMJ and CMJA height in elite academy players showed body mass, standing height and age to be significant explanatory variables (Tables 8.3, 8.4 and 8.5). The peak rate of change in RJ (1.86 $cm.yr^{-1}$), CMJ (2.00 $cm.yr^{-1}$) and CMJA (2.41 $cm.yr^{-1}$) height occurred at 13.3 years (Figures 8.6, 8.8 and 8.10), a year after the reported PHV. Similarly, in a longitudinal sample of 220 Belgian boys, peak rate of change in strength related tests, including vertical jump (explosive strength), arm pull (static shoulder strength) and bent arm hand (strength endurance) occurred after PHV (Beunen et al., 1988). The present results suggest that peak rate of change in vertical jump (13.3 years) is closer to PWV (13.8 years) than PHV (12.3 years), this supports the suggestion that strength and motor performance are more coincident with PWV (Beunen and Malina, 1988). Beunen and Malina (1988) state that the adolescent spurt in muscle tissue also occurs after PHV and is more coincident with PWV, suggesting that muscle tissue increases first in mass and then in strength during male adolescence. The authors further suggest that changes in the metabolic and contractile features of muscle tissue as adolescence progresses and/or neuromuscular maturation affect strength performance. More recently it has also been suggested that improved movement co-ordination is an important contributor to muscle force gains observed during growth and maturation, particularly when assessments are based on more complex, multi-joint exercises such as vertical jump and sprint running (Van Praagh and Dore, 2002).

Similar to vertical jump performance, multilevel multiplicative allometric analysis of 10 m and 20 m speed showed body mass, standing height and age to be significant explanatory variables (Tables 8.6 and 8.7). However, unlike vertical jump performance the peak rate of change in 10 m (0.13 $m.s.yr^{-1}$) and 20 m (0.17 $m.s.yr^{-1}$) speed occurred earlier at the time of PHV (12.3 years) (Figures 8.12 and 8.14). Beunen and colleagues (1988) observed a similar pattern in the speed related tests, including shuttle run (running speed and agility) and plate tapping (upper body limb speed) they conducted with Belgian boys with peak rate of change occurring before PHV. It has been stated that in contrast to strength, the fact speed reaches peak rate of change prior to PHV indicates that it is more coincident with the adolescent spurt in leg length (Beunen and Malina, 1988). Furthermore, Beunen and Malina (1988) have suggested that there may be more optimal strength-lever arm relationships at this time, which may lead to improved running performance.

Multilevel multiplicative allometric analysis of agility also showed body mass, standing height and age to be significant explanatory variables (Table 8.8). However, the peak rate of change in agility (0.15 m.s.yr^{-1}) was found to occur at 7.3 years, well in advance of PHV (Figure 8.16). It has been reported that an agility test can discriminate elite soccer players from the general population better than any other field test of physical performance (Raven et al., 1976; Reilly et al., 2000). Based on such observations it is reasonable to suggest that the greatest physical improvements made as a result of systematic soccer training are evident in relation to a players' agility. A players' first exposure to systematic soccer training within the academy system usually occurs in the U9 age group. It may be suggested that as a result of this initial exposure to systematic soccer training that the greatest improvements in a players' agility performance are therefore witnessed in the youngest age groups. Another explanation as to why the rate of change in the agility test performance follows a different pattern to the rate of change in all the other performance tests may relate to the nature of the agility test (Figure 3.3). The agility test used in the present study measures the players' ability to change direction at speed, therefore the advantage on such a test of being taller and possessing a longer stride length may not be so great, unlike straight line sprint speed where a longer stride length is an obvious advantage. This may explain why the rate of change in agility test speed (Figure 8.16) and standing height velocity (Figure 8.2) follow such different patterns, whereas the rate of change in both 10 m and 20 m sprint speed (Figures 8.12 and 8.14, respectively) follow a pattern that is closely related to standing height velocity (Figure 8.2).

Whilst aerobic performance during growth and maturation has been extensively studied (Armstrong and Welsman, 1994) with researchers having modelled growth changes in aerobic function (Nevill et al., 1998), comparatively little attention has been given to short burst, maximal-intensity physical performance lasting only a few seconds (Van Praagh and Dore, 2002). This has been considered surprising given the popularity of 'multiple sprint sports' where children are primarily involved in short-term high intensity exercise (Williams, 1987). The lack of paediatric literature in this area makes comparisons of the present results difficult as the physical performance tests that have been used (vertical jump, sprint speed and agility) all focus on short-term high intensity exercise that is specific to soccer.

In summary, the present longitudinal study is the first of its kind to use multilevel modelling analysis to provide an understanding of developmental changes in physical performance in elite child and adolescent soccer players. The results this study suggest that the peak rate of change in sprint speed in adolescent soccer players coincides with peak height velocity, but the peak rate of change in vertical jump occurs later and closer to their peak in weight velocity. In the current study the pattern in the rate of change in agility was different from that seen in all other variables and the peak change occurred in the youngest players.

8.4.1 Practical applications

This study provides practitioners with a more detailed understanding of the influence of growth on physical performance in elite child and adolescent soccer players. The important influences of peak height velocity and peak weight velocity on physical performance development are highlighted by the current study. In light of this practitioners should endeavour to measure longitudinal changes in the standing height and body mass of their young players'. The study also presents practitioners with an example of appropriate multilevel modelling structures (additive polynomial structure and multiplicative allometric structure) with which to analyse longitudinal growth data.

CHAPTER 9

PHYSICAL PERFORMANCE AND PLAYING ABILITY: IMPLICATIONS FOR THE PROCESS OF TALENT IDENTIFICATION

9.1 ELITE AND NON-ELITE PLAYERS: ANTHROPOMETRIC AND PHYSICAL PERFORMANCE CHARACTERISTICS

9.1.1 INTRODUCTION

Soccer is the most popular sport in the world and is performed by men and women, children and adults with varying levels of ability (Stolen et al., 2005). The requirements for soccer play are multifactorial and include numerous physical, technical and tactical factors (Reilly et al., 2000). Researchers have indicated that a number of physical and anthropometric prerequisites are essential to compete at the elite level in soccer (Reilly, Bangsbo and Franks, 2000). In relation to this it is suggested that anthropometric and physical performance profiling has an important role to play as part of a holistic monitoring of talented young players (Reilly, Bangsbo and Franks, 2000).

A number of studies have investigated differences in physical performance between elite and non-elite senior players (Brewer and Davis, 1992; Kollath and Quade, 1993; Cometti et al., 2001). Kollath and Quade (1993) observed that German professional players were faster over short sprints (5, 10, 20 and 30 m) than their amateur counterparts. Observations of this nature have been used to establish the distinguishing characteristics of elite players.

Other researchers have undertaken comparisons between elite and sub-elite young players (Hansen et al, 1999; Reilly et al, 2000; Le Gall et al., 2010). Reilly and colleagues (2000) established that elite players had higher aerobic power, were more agile and had a better vertical jump. However, the study by Reilly and colleagues (2000) and the sparse number of other published studies are limited in terms of the small number, and narrow age and ability range of the players examined. For example, the young players studied by Reilly and colleagues (2000) included 16 elite (associated with a professional club) and 15 sub-elite (played with amateur and/or school team), with an average age of 16.4 years, respectively.

To our knowledge, no study has compared the anthropometric and physical performance characteristics of young male soccer players across the full spectrum of ages and abilities, from non-playing school pupils to international players. Information of this nature would be of particular interest to coaches, sports scientists and teachers who are involved in talent identification and development of young players. Therefore, the purpose of this study was to examine the anthropometric and physical performance characteristics of elite and non-elite young players, whilst identifying differences and developing performance standards for each ability group. The hypothesis to be tested was that soccer ability group (non-players vs. school players; school pupils vs. academy players; club academy players vs. international academy players) could be distinguished on the basis of anthropometric and/or physical performance characteristics.

9.1.2 METHODS

9.1.2.1 Participants

A total of 2,305 subjects (age 14.3±2.1 years; height 164.3±13.6 cm; body mass 55.2±14.2 kg) participated in this study. All the subjects were registered at one of twelve professional soccer club academies or attended one of two schools in England. The main groups and subgroups which formed the basis of the analysis are outlined in Table 9.1.1.

Table 9.1.1. Distribution of subjects.

Main Group	Sub Group	Age Group (n)								Total (n)
		U11	U12	U13	U14	U15	U16	U17	U18	
Academy Players (elite)	International Players	n/a	n/a	n/a	n/a	7	23	29	39	98
	Club Players	236	269	248	288	245	171	107	123	1687
School Pupils (non-elite)	School Players	14	20	32	48	54	18	14	9	209
	Non Players	11	58	53	78	57	30	15	9	311

9.1.2.2 Procedures

A detailed description of the procedures and physical performance testing protocol can be found in sections 3.3 and 3.4. The school pupils were measured and tested in their respective age-group classes over the course of the 2003-2004 and 2004-2005 academic years.

9.1.2.3 Statistical analysis

Data were analysed using SPSS (Version 16.0, Chicago, Illinois, USA) and MLwiN (Version 2.16, Bristol, U.K.). Descriptive statistics were calculated. Two-way analysis of variance (ANOVA) was used to investigate differences in anthropometric and physical performance variables between the different playing ability groups (non-players vs. school players; school pupils vs. academy players; club academy players vs. international academy players), age groups and the interaction between playing ability group and age. When a significant interaction playing ability group*age was found post hoc pairwise bonferroni analysis by age group was conducted. Binomial logistic regression was used to compare the anthropometric and physical performance characteristics of the different playing ability groups (non-players vs. school players; school pupils vs. academy players)*. Statistical significance was accepted at the 95% confidence level ($p \leq 0.05$). Values are reported as mean (±SD).
*Odds ratios are presented from the binomial logistic regression analysis. Bland and Altman (2000, pp. 1468) state, “the odds are a way of representing probability…….the odds is the ratio of the probability that the event of interest occurs to the probability that it does not”. An odds ratio of 1.0 suggests that there is an equal probability of an event occurring or not occurring. However, an odds ratio of >1.0 suggests that there is a greater probability of an event occurring, whilst an odds ratio of <1.0 suggests that there is less probability of an event occurring.

9.1.3. RESULTS

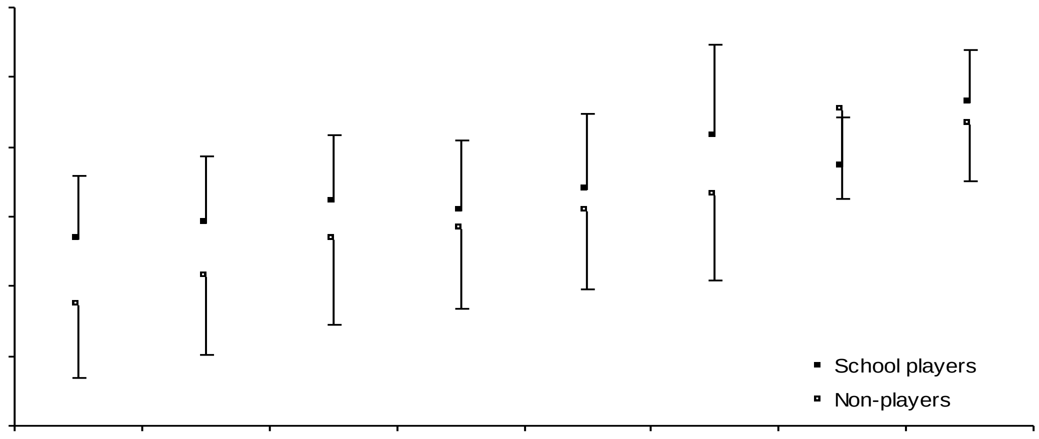
9.1.3.1 Non-players vs. school players

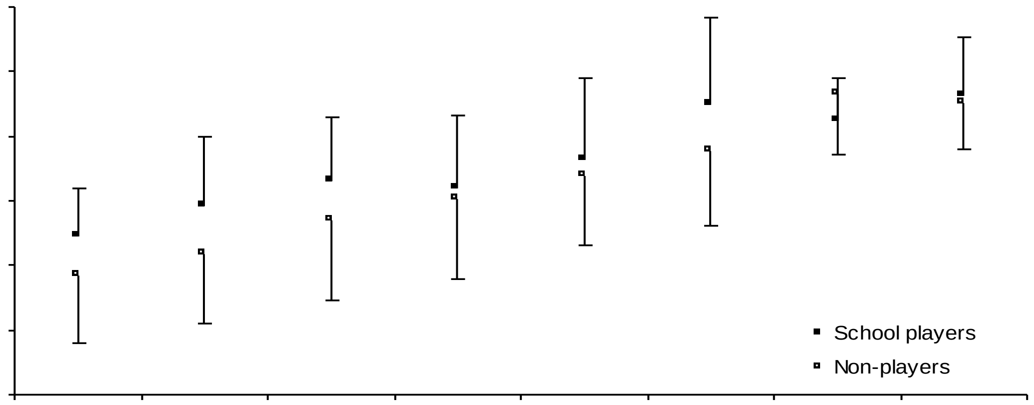
No significant differences were found between non-players and school players in age, standing height, body mass and BMI (Table 9.1.2). School players displayed significantly higher reciprocal ponderal index and ectomorphy values in comparison to non-players ($p<0.05$; Table 9.1.2). The RJ of school players was significantly higher than non-players ($p<0.05$), no significant difference in CMJ and CMJA performance was observed between school players and non-players (Figure 9.1.1). The school players were significantly faster on the sprint (10 m and 20 m) and agility test in comparison to the non-players ($p<0.01$; Figure 9.1.2). A significant interaction playing ability group*age was found in the 20 m sprint test ($p<0.05$; Figure 9.1.2). The 20 m sprint of the school players was significantly faster in all but the U17 age group, the largest difference between school players and non-players occurring at U15, 3.48±0.2 vs. 3.81±0.4 s, respectively ($p<0.01$; Figure 9.1.2). No significant difference in estimated $\dot{V}O_{2peak}$ between non-players and school players was found (Figure 9.1.3). The binomial logistic regression analysis suggests that, compared with non-players, school players are 0.96 times more likely to have a lower body mass ($p<0.05$; Table 9.13). It was also suggested that school players were 3.28 and 5.80 times more likely to be faster over the 10 m sprint and during the agility test, respectively, than non-players ($p<0.05$; Table 9.13).

Table 9.1.2. Anthropometric and body shape characteristics of non-players vs. school players (mean±SD).

Variable	Subjects	Age Group							
		U11	U12	U13	U14	U15	U16	U17	U18
Number (n)	School Players	14	20	32	48	54	18	14	9
	Non-Players	11	58	53	78	57	30	15	9
Chronological Age (yrs)	School Players	11.3±0.3	12.2±0.3	13.3±0.3	14.0±0.4	15.1±0.3	16.0±0.3	16.9±0.2	17.8±0.3
	Non-Players	11.3±0.3	12.3±0.3	13.2±0.3	14.2±0.3	15.2±0.3	16.2±0.3	17.1±0.3	17.9±0.3
Standing Height (cm)	School Players	148.2±7.1	150.0±9.9	157.1±6.7	168.1±7.9	171.5±8.1	175.8±6.0	181.0±7.0	176.6±6.9
	Non-Players	147.0±6.0	152.4±8.3	156.6±7.8	166.1±8.5	171.9±6.8	177.0±5.8	183.1±4.8	181.7±7.3
Body mass (kg)	School Players	39.5±6.1	41.9±8.8	47.7±6.9	56.3±8.9	62.7±13.3	66.1±7.9	68.4±9.3	67.0±5.9
	Non-Players	41.3±6.0	46.8±9.6	48.5±9.9	56.1±11.4	63.0±12.0	69.2±8.6	73.4±6.9	76.7±6.4
BMI	School Players	17.9±1.8	18.4±2.2	19.3±2.1	19.9±2.5	21.1±3.2	21.3±1.5	20.8±2.3	21.5±1.9
	Non-Players	19.0±1.8	20.1±3.5	19.7±3.4	20.2±3.3	21.3±3.6	22.1±2.4	21.9±1.8	23.2±1.8
Reciprocal Ponderal Index[a]	School Players	43.7±1.4	43.5±1.6	43.5±1.6	44.1±1.8	43.5±1.8	43.6±1.0	44.4±1.6	43.6±1.5
	Non-Players	42.7±1.3	42.6±2.6	43.4±2.4	43.8±2.2	43.5±2.3	43.3±1.6	43.9±1.3	42.9±1.5
Ectomorphy[a]	School Players	3.4±1.1	3.3±1.1	3.3±1.1	3.7±1.3	3.3±1.3	3.3±0.7	4.0±1.2	3.3±1.1
	Non-Players	2.7±0.9	2.8±1.8	3.2±1.6	3.5±1.5	3.3±1.6	3.1±1.1	3.5±0.9	2.8±1.1

Main effect non-players / school players, [a]$p<0.05$; main effect age group, $p<0.01$; interaction non-players / school players*age, NS.





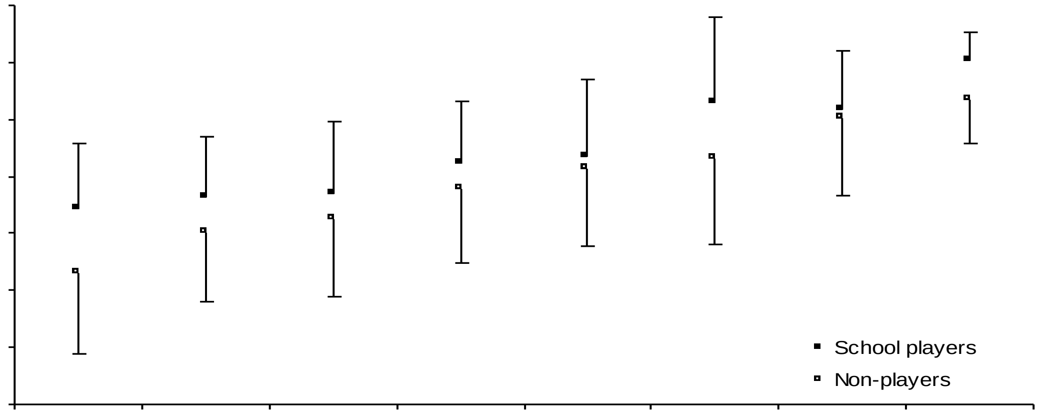


Figure 9.1.1. Vertical jump performance of non-players vs. school players by age group (mean±SD).
Main effect non-players / school players, RJ $p<0.05$, CMJ and CMJA NS; main effect age group, $p<0.01$; interaction non-players / school players*age, NS.

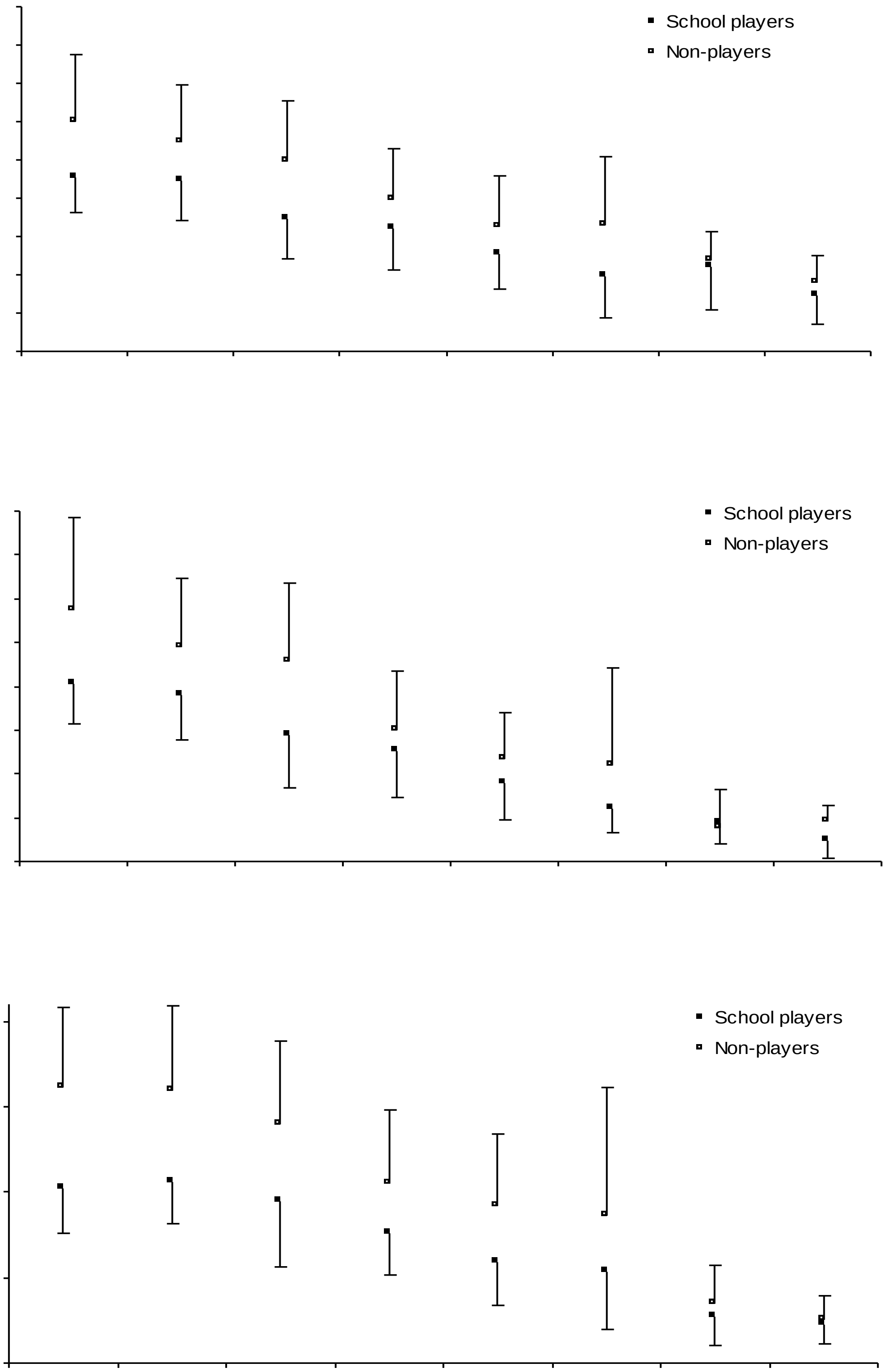


Figure 9.1.2. Sprint and agility performance of non-players vs. school players by age group (mean±SD).
Main effect non-players / school players, $p<0.01$; main effect age group, $p<0.01$; interaction school pupils / academy players*age, sprint 20 m $p<0.05$, post hoc pairwise bonferonni analysis by age group, *$p<0.01$, **$p<0.05$.

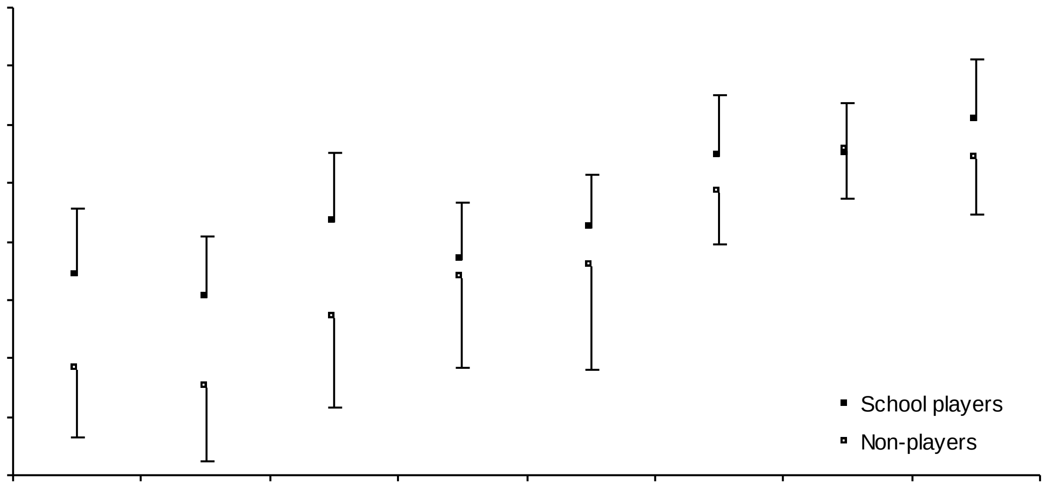


Figure 9.1.3. Estimated $\dot{V}O_{2peak}$ of non-players vs. school players (mean±SD).
Main effect non-players / school players, NS; main effect age group, p<0.01; interaction school pupils / academy players*age, NS.

Table 9.1.3. Binomial logistic regression analysis of non-players vs. school players.

Variable	ß	SE	Odds Ratio ($e^{ß}$)	Lower 95%CI	Upper 95%CI	Probability
Intercept	0.684**	0.153				
Body mass	-0.036**	0.009	0.96	0.95	0.98	0.657
10m Speed	1.189**	0.338	3.28	1.69	6.37	0.867
Agility Speed	1.757**	0.338	5.80	2.99	11.24	0.920

**p<0.05

9.1.3.2 School pupils vs. academy players

No significant differences in age, standing height, reciprocal ponderal index and ectomorphy were found between school pupils and academy players (Table 9.1.4). A significant difference in body mass and BMI values was observed between school pupils and academy players (p<0.05; Table 9.1.4). A significant interaction school pupils / academy players*age was found for age, BMI, reciprocal ponderal index and ectomorphy (p<0.01; Table 9.1.4). A significant difference in vertical jump performance (RJ; CMJ; CMJA) between academy players and school pupils was found ($p<0.01$; Figure 9.1.4). A significant interaction school pupils / academy players*age was evident on all vertical jump tests ($p<0.01$ RJ, CMJA; $p<0.05$ CMJ; Figure 9.1.4). Differences were evident in CMJ performance across all age groups when school pupils and academy players were compared, the largest difference was found at U15, 32.5±5.8 vs. 37.0±5.0 cm, respectively ($p<0.01$; Figure 9.1.4). A significant difference in sprint (10 m and 20 m) and agility performance between academy players and school pupils was found ($p<0.01$; Figure 9.1.5). A significant interaction school pupils / academy players*age was evident on all sprint (10 m and 20 m) and agility tests ($p<0.01$; Figure 9.1.5). Differences were evident in sprint (10 m and 20 m) and agility performance across all age groups when school pupils and academy players were compared, the largest difference was found on the agility test at U12, 5.56±0.5 vs. 4.68±0.3 s, respectively ($p<0.01$; Figure 9.1.5). The better sprint (10 m and 20 m) and agility performance of the academy players was further illustrated by the distance on average which they led the school pupils by in the respective tests (Figure 9.1.6). The biggest distance that the academy players led the school pupils in the sprint tests (10 m and 20 m) were found at U12 (0.87 m) and U13 (1.90 m), respectively (Figure 9.1.6). A significant difference in estimated $\dot{V}O_{2peak}$ between academy players and school pupils was found ($p<0.01$; Figure 9.1.7). A significant interaction school pupils / academy players*age was evident for estimated $\dot{V}O_{2peak}$ ($p<0.01$) with significant differences across all age groups, the largest difference being at U12, 34.3±6.9 vs. 47.7±4.4 $ml.kg^{-1}.min^{-1}$, respectively ($p<0.01$; Figure 9.1.7). The binomial logistic regression analysis suggests that school pupils are more likely to be older and taller than academy players ($p<0.05$; Table 9.15). Academy players are 6.42 times more likely to be quicker over 10 m and almost 60.34 times more likely to have better agility (Table 9.15).

Table 9.1.4. Anthropometric and body shape characteristics of school pupils vs. academy players (mean±SD).

Variable	Subjects	Age Group							
		U11	U12	U13	U14	U15	U16	U17	U18
Number (n)	School Pupils	25	78	85	126	111	48	29	18
	Academy Players	236	269	248	288	252	194	136	162
Chronological age (yrs)	School Pupils	11.3±0.3	12.3±0.3	13.2±0.3	14.1±0.3	15.2±0.3	16.1±0.3	17.0±0.3	17.9±0.3
	Academy Players	11.2±0.3	12.2±0.3*	13.2±0.3	14.2±0.3	15.2±0.4	16.1±0.4	17.2±0.4*	18.1±0.4*
Standing Height (cm)	School Pupils	147.7±6.5	151.8±8.8	156.8±7.4	166.9±8.3	171.7±7.5	176.6±5.8	182.1±6.0	179.2±7.3
	Academy Players	145.3±6.8	151.6±7.5	157.6±8.7	166.6±8.4	171.9±8.0	175.9±6.0	178.0±6.7	179.0±5.7
Body mass (kg)[a]	School Pupils	40.3±6.0	45.5±9.6	48.2±8.9	56.2±10.5	62.9±12.6	68.1±8.3	71.0±8.4	71.8±7.8
	Academy Players	37.6±5.4	42.0±6.5	46.9±8.1	55.5±9.2	62.2±9.3	67.2±7.8	70.7±7.9	73.0±7.0
BMI[a]	School Pupils	18.4±1.8	19.7±3.3	19.5±3.0	20.1±3.0	21.2±3.4	21.8±2.1	21.4±2.0	22.4±2.0
	Academy Players	17.7±1.6**	18.2±1.7*	18.8±1.8**	19.9±1.9	20.9±2.0	21.7±1.8	22.3±1.5*	22.7±1.6
RPI	School Pupils	43.3±1.4	42.9±2.4	43.4±2.1	43.9±2.1	43.5±2.1	43.4±1.4	44.1±1.4	43.2±1.5
	Academy Players	43.5±1.3	43.8±1.3*	43.9±1.4	43.9±1.3	43.6±1.3	43.4±1.2	43.2±1.0*	43.0±1.2
Ectomorphy	School Pupils	3.1±1.1	2.9±1.6	3.2±1.5	3.6±1.5	3.3±1.4	3.2±1.0	3.7±1.0	3.1±1.1
	Academy Players	3.3±0.9	3.5±0.9*	3.6±1.0	3.5±0.9	3.3±0.9	3.2±0.9	3.0±0.7*	2.9±0.9

Main effect school pupils / academy players, [a]$p<0.05$; main effect age group, $p<0.01$; interaction school pupils / academy players*age, $p<0.05$, post hoc pairwise bonferonni analysis by age group, *$p<0.01$, **$p<0.05$.

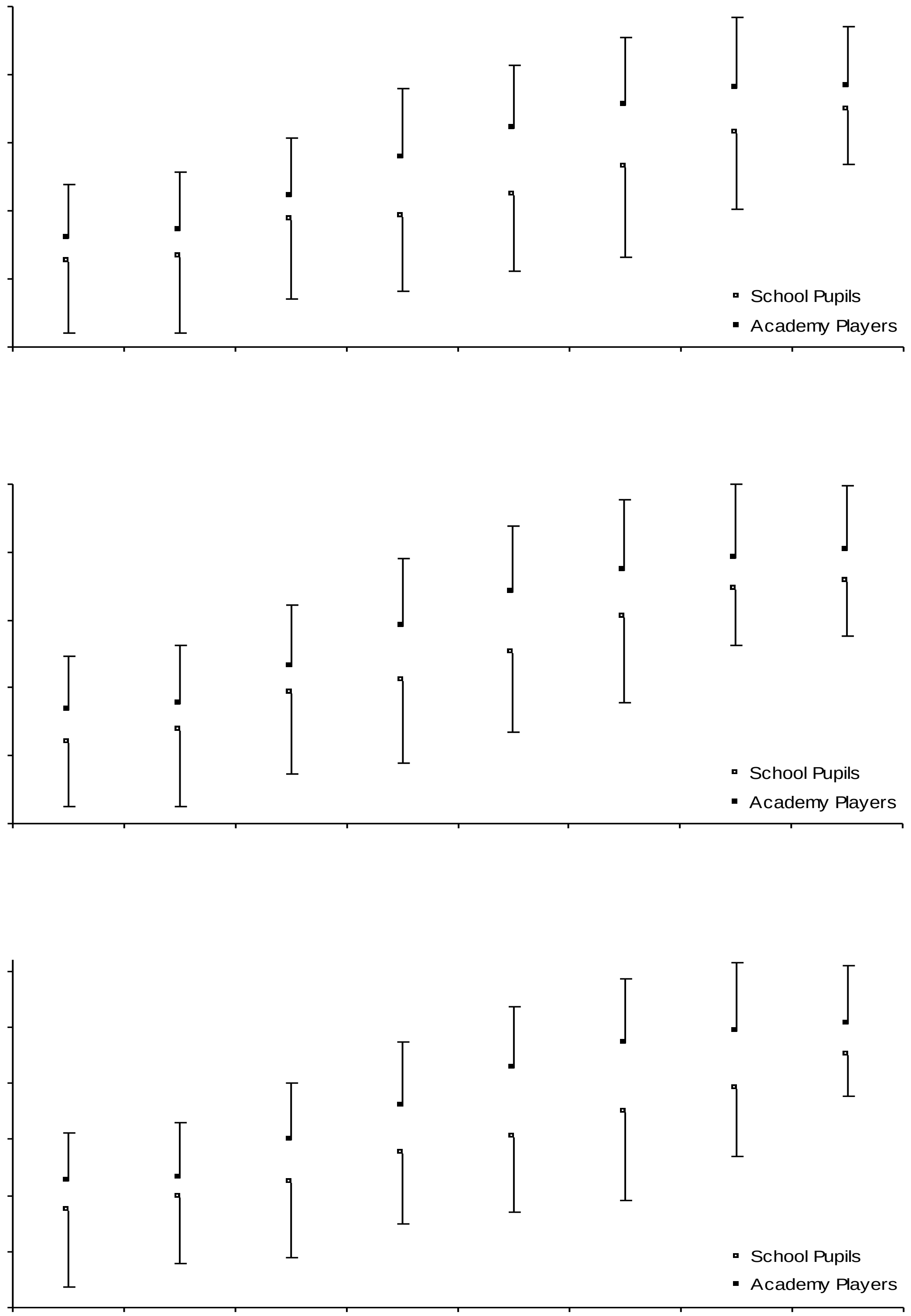


Figure 9.1.4. Vertical jump performance of school pupils vs. academy players by age group (mean±SD).
Main effect school pupils / academy players, $p<0.01$; main effect age group, $p<0.01$; interaction school pupils / academy players*age, $p<0.05$, post hoc pairwise bonferonni analysis by age group, *$p<0.01$, **$p<0.05$.

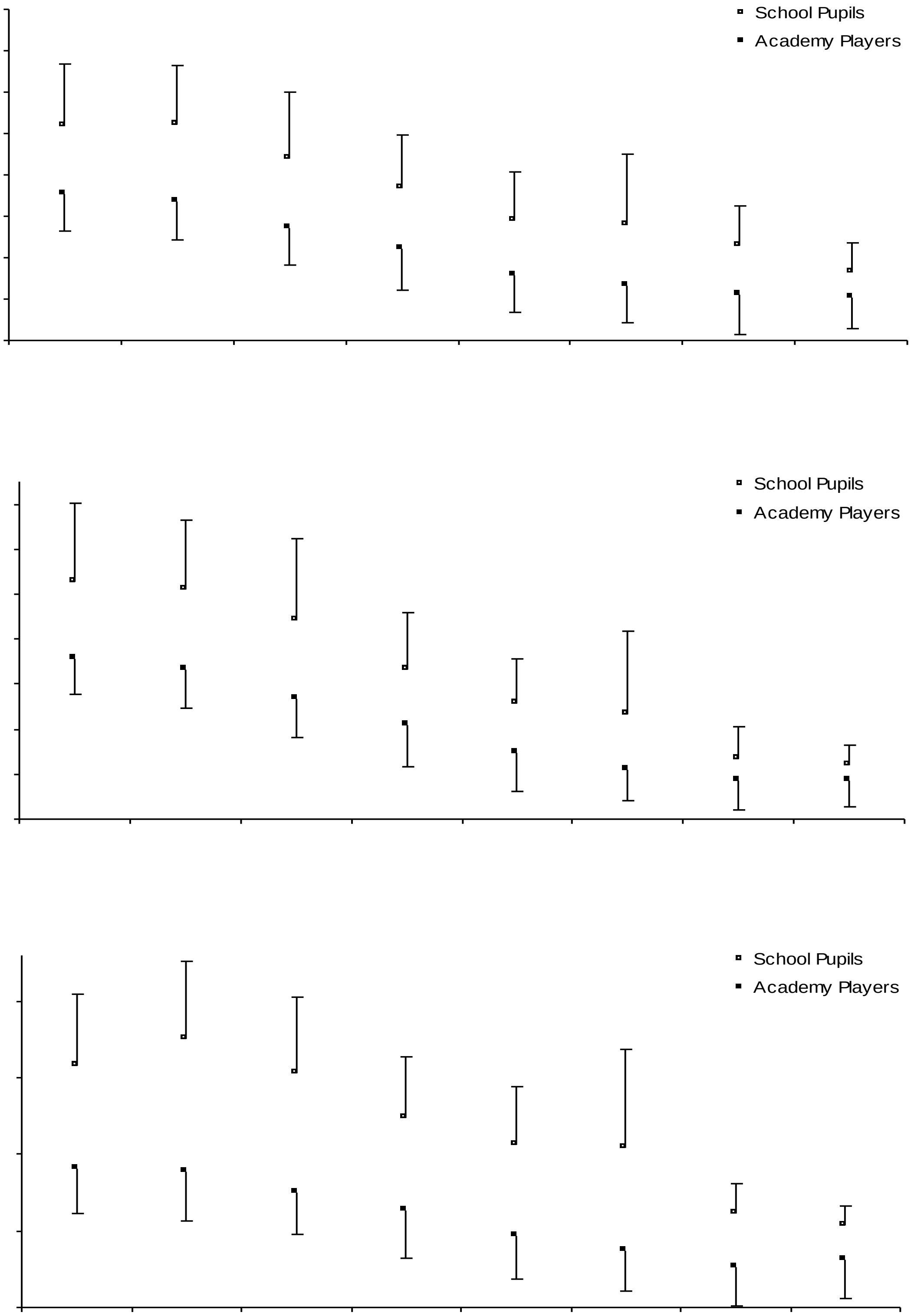


Figure 9.1.5. Sprint and agility performance of school pupils vs. academy players by age group (mean±SD).
Main effect school pupils / academy players, p<0.01; main effect age group, p<0.01; interaction school pupils / academy players*age, p<0.05, post hoc pairwise bonferonni analysis by age group, *p<0.01, **p<0.05.

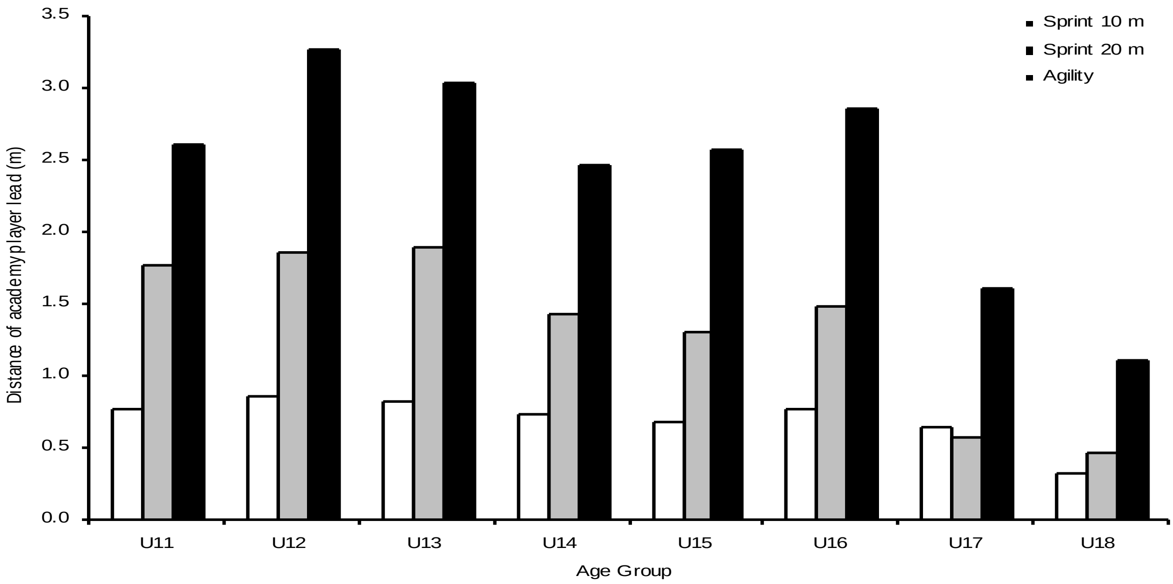


Figure 9.1.6. Lead of academy players over school pupils in 10 m and 20 m sprint and agility performance.

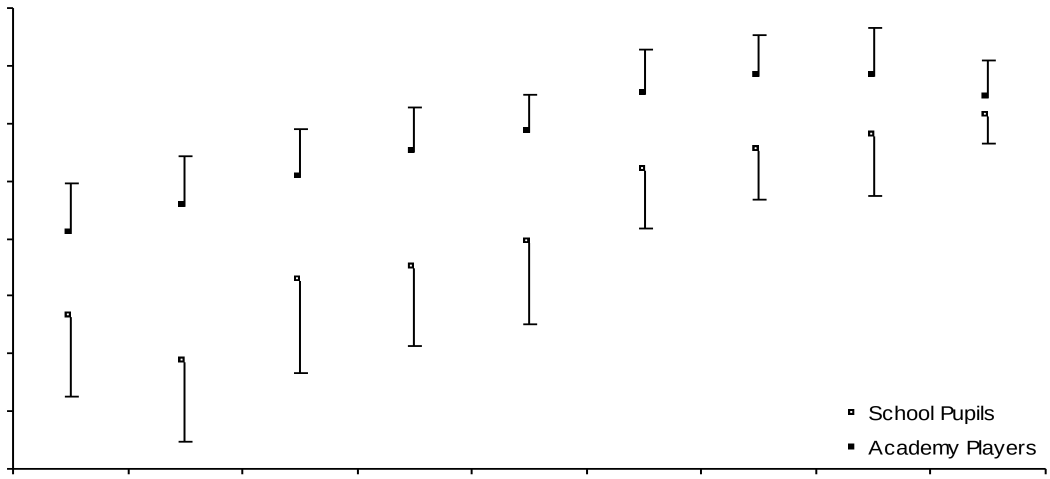


Figure 9.1.7. Estimated $\dot{V}O_{2peak}$ of school pupils vs. academy players by age group (mean±SD).

Main effect school pupils / academy players, $p<0.01$; main effect age group, $p<0.01$; interaction school pupils / academy players*age, $p<0.05$, post hoc pairwise bonferonni analysis by age group, *$p<0.01$, **$p<0.05$.

Table 9.1.5. Binomial logistic regression analysis of school pupils vs. academy players.

Variable	ß	SE	Odds Ratio ($e^{ß}$)	Lower 95%CI	Upper 95%CI	Probability
Intercept	2.514**	0.105				
Age	-0.569**	0.082	0.57	0.48	0.66	0.875
Height	-0.028**	0.010	0.97	0.95	0.99	0.923
10m Speed	1.859**	0.323	6.42	3.41	12.09	0.988
Agility Speed	4.100**	0.312	60.34	32.74	111.22	0.999

**p<0.05

9.1.3.3 Club academy players vs. international academy players

The only significant difference in anthropometric, body shape and physical performance characteristics between club academy players and international academy players was found in the RJ ($p<0.05$; Table 9.1.6).

Table 9.1.6. Anthropometric and physical performance characteristics of club academy players vs. international academy players (mean±SD).

Variable	Subjects	Age Group			
		U15	U16	U17	U18
Number (n)	International academy players	7	23	29	39
	Club academy players	245	171	107	123
Chronological Age (yrs)[a]	International academy players	15.2±0.5	16.1±0.4	17.1±0.3	18.0±0.4
	Club academy players	15.2±0.4	16.1±0.4	17.2±0.4	18.1±0.3
Standing Height (cm)	International academy players	170.1±9.3	177.3±6.2	177.9±6.2	180.2±6.2
	Club academy players	172.0±7.9	175.8±6.0	178.0±6.8	178.7±5.6
Body mass (kg)	International academy players	59.4±11.1	69.3±8.7	70.3±6.0	73.5±7.2
	Club academy players	62.3±9.2	67.0±7.7	70.8±8.3	72.8±6.9
BMI	International academy players	20.3±2.0	22.0±2.1	22.2±1.4	22.6±1.7
	Club academy players	21.0±2.0	21.6±1.8	22.3±1.5	22.8±1.6
RPI	International academy players	43.9±1.0	43.3±1.4	43.2±1.1	43.1±1.2
	Club academy players	43.6±1.3	43.4±1.2	43.2±1.0	42.9±1.1
Ectomorphy	International academy players	3.5±0.8	3.1±1.0	3.0±0.8	3.0±0.9
	Club academy players	3.3±0.9	3.2±0.9	3.0±0.7	2.8±0.8
RJ (cm)[a]	International academy players	36.7±3.5	40.5±4.7	39.5±5.4	38.7±4.4
	Club academy players	36.0±4.7	37.3±5.0	38.9±5.1	39.2±4.5
CMJ (cm)	International academy players	34.9±2.7	40.5±5.0	40.0±5.9	39.8±5.2
	Club academy players	37.0±5.0	38.4±5.2	39.4±5.4	40.2±4.6
CMJA (cm)	International academy players	40.3±5.1	46.8±4.9	46.2±7.2	45.4±6.0
	Club academy players	42.3±5.5	44.2±5.8	45.4±5.9	46.4±5.0
10 m Sprint (s)	International academy players	1.75±0.1	1.73±0.1	1.71±0.1	1.72±0.1
	Club academy players	1.76±0.1	1.73±0.1	1.71±0.1	1.70±0.1
20 m Sprint (s)	International academy players	3.07±0.2	3.00±0.2	2.98±0.1	2.99±0.1
	Club academy players	3.09±0.2	3.02±0.1	2.97±0.1	2.96±0.1
Agility Ave (s)	International academy players	4.14±0.4	4.13±0.3	4.01±0.2	4.15±0.2
	Club academy players	4.27±0.3	4.18±0.3	4.08±0.3	4.09±0.2

Main effect club academy players / international academy players, [a]$p<0.05$; main effect age group, $p<0.01$; interaction non-players / school players*age, NS.

Table 9.1.7. Estimated $\dot{V}O_{2peak}$ of club academy players vs. international academy players (mean±SD).

Variable	Subjects	Age Group			
		U15	U16	U17	U18
Number (n)	International academy players	4	6	10	10
	Club academy players	69	58	31	26
Chronological Age (yrs)	International academy players	15.1±0.4	16.3±0.2	17.0±0.3	17.9±0.4
	Club academy players	15.2±0.4	16.1±0.4	17.1±0.4	18.1±0.4
$\dot{V}O_{2peak}$ ($ml.kg^{-1}.min^{-1}$)	International academy players	56.6±3.7	58.2±1.2	58.9±4.1	61.1±3.9
	Club academy players	54.0±3.3	57.4±4.2	59.1±3.5	58.3±4.2

Main effect club academy players / international academy players, NS; main effect age group, $p<0.01$; interaction non-players / school players*age, NS.

9.1.4 DISCUSSION

The key findings of the present study were that agility best distinguished school players from non-players (school players being 5.80 times more likely to be faster on the agility test ($p<0.05$; Table 9.1.3)) and academy players from school pupils (academy players being 60.34 times more likely to be faster on the agility test ($p<0.05$; Table 9.1.5), whilst international academy players were only distinguished from club academy players by RJ height ($p<0.05$; 9.1.6).

At the non-elite level the comparison between non-players and school team players revealed significant differences in body mass, with school players 0.96 times more likely to be lighter ($p<0.05$; Table 9.1.3) and body shape, with higher values of reciprocal ponderal index and ectomorphy being evident in the school players ($p<0.05$; Table 9.1.2). In relation to senior professional players it has been suggested that taller, more linear players with a high reciprocal ponderal index are more successful (Nevill, Holder and Watts, 2009). The current findings would appear to suggest that even at the non-elite level the lighter but taller, more linear school pupils are being more readily selected for school teams.

In comparison to non-players the school players were also found to perform better on the RJ test ($p<0.05$; Figure 9.1.1). However, the main differences in physical performance between the non-players and school players were observed on the sprint (10 m and 20 m) and agility test, where school players were found to be significantly faster ($p<0,01$; Figure 9.1.2). For example, in comparison to non-players the school players were 3.28 times more likely to faster over the 10 m sprint ($p<0.05$; Table 9.1.5). Whilst short sprint and agility capabilities are considered key attributes in elite soccer players (Reilly et al, 2000) no studies have examined the nature of such attributes at the non-elite level of soccer. The present findings would suggest that even at the non-elite level speed and agility are important attributes for players to possess as it is these physical performance characteristics which discriminate them from non-players.

In the present study no difference in standing height was observed between elite academy players and non-elite school pupils (Table 9.1.4) although binomial logistic regression analysis suggested that the school team players were more likely to be older and taller than the elite academy players ($p<0.05$; Table 9.1.5). This finding is not in accordance with earlier studies where elite players have been found to be taller compared to the non-elite group (Cacciari et al., 1990; Hansen et al., 1999). Hansen and colleagues (1999) compared 48 elite and 50 non-elite Danish players, distinguishing elite and non-elite players as either playing for the best or worst ranked team at their club, respectively. In this study the elite group consists of players at English professional soccer academies, whilst the non-elite group is made up of secondary school pupils. These groups are arguably more extensive than those used by Hansen and colleagues (1999) and therefore one may have expected the elite group to be taller in comparison to the non-elite group. The comparatively larger number of participants in this study, with 1785 elite players and 520 non-elite school pupils may have diluted any apparent differences. This finding would also appear to contradict the argument that increased selection opportunities in soccer tend to favour older and physically taller boys (Brewer, Balsom and Davis, 1995). Indeed, the U12 school pupils in this study were significantly older than their academy counterparts ($p<0.01$), with only the U17 and U18 academy players being comparatively older ($p<0.01$; Table 9.1.4). The current findings may be the result of relative age effect which is even more apparent in non-elite school soccer where older and taller boys may be selected for the school teams. However, based on the present findings it would appear too simplistic to merely suggest that selection opportunities in elite soccer favour older and taller boys.

Body mass and BMI was significantly lower in the elite academy players in comparison to the non-elite school pupils ($p<0.05$; Table 9.1.4). This finding may be related to an earlier observation that regular physical training in children generally results in an increase in lean body mass and corresponding decrease in body fat (Bailey and Mirwald, 1988). The systematic training of elite academy players may well account for the present finding. However, as body fat measurements were not taken in the current study this explanation for the finding of academy players being lighter in comparison to school pupils can only be surmised.

In the present study, academy players were found to have significantly higher vertical jump capacities than school pupils (RJ, CMJ and CMJA) ($p<0.01$; Figure 9.1.4). With the exception of the RJ (U11 and U18) and CMJA (U11) academy players performed significantly greater vertical jump heights in comparison to school pupils (Figure 9.1.4). The superior jumping performance of the academy players compared to the school pupils was quite substantial. For example, on average the academy players CMJA performance was 6.1 cm higher than the school pupils in the U15 and U16 age groups. Not all studies have found jumping ability to differ between different standards of players. Cometti and colleagues (2001) found no differences to exist in RJ or CMJ performance between senior French professional and amateur soccer players. It was suggested that soccer training may not represent an adequate training stimulus to develop jumping ability (Cometti et al., 2001). Although the results of the present study are not in agreement with the findings of Cometti and colleagues (2001) they do support the more recent suggestion that jumping capacity can discriminate across various age categories and different standards of play (Le Gall et al., 2010).

In this study the academy players sprint speed (10 m and 20 m) was significantly faster than that of the school pupils ($p<0.01$), a significant difference in sprint performance (10 m and 20 m) was found in each age group studied (U11 to U18) (Figure 9.1.5) with academy players being found to be 6.42 times more likely to be quicker over a 10 m sprint than the school pupils ($p<0.05$; Table 9.1.5). The greatest differences in sprint speed between the academy players and school pupils were evident in the younger age groups (Figure 9.1.5). For example, the U12 academy players were 0.19 s and 0.36 s faster over 10 m and 20 m, respectively, in comparison to the U12 school pupils ($p<0.01$; Figure 9.1.5). Owing to their faster sprint speed, the U12 academy players were on average 0.87 m and 1.87 m ahead of the U12 school pupils after 10 m and 20 m, respectively (Figure 9.1.6). Such differences are of considerable importance when put into the context of a match. It has been suggested that the ability of players to perform short sprints is often crucial for the match outcome (Wragg et al., 2000). This present finding is in accordance with previous studies where elite players have demonstrated better sprint capabilities than their non-elite counterparts (Brewer and Davis, 1992; Kollath and Quade, 1993; Cometti et al., 2001). Brewer and Davis (1992) found senior English professional players to be faster in comparison to semi-professional players when sprinting over 15 m and 40 m. Similarly, Cometti and colleagues (2001) found senior French professional players to be faster than their amateur counterparts in terms of 10 m sprint performance, although no such differences were evident over 30 m. These findings together with the results of the current study further emphasise the relative importance of sprint performance over short distances in soccer.

The present study also found that the agility performance of the academy players were significantly faster than the school pupils ($p<0.01$), a significant difference in agility performance was found in each age group studied (U11 to U18) (Figure 9.1.5). The differences in agility performance were even more marked than those observed in sprint performance, with the academy players being 60.34 times more likely to be quicker than the school pupils on the agility test ($p<0.05$; Table 9.1.5). For example, the U12 academy players were on average 0.88 s faster on the agility test than the U12 school pupils. Such a time difference would equate to the U12 academy players being 3.28 m ahead of the U12 school pupils on the 20.8 m agility test (Figure 9.1.6). The combination of better sprint speed and agility capabilities could be decisive in influencing positive outcomes during a match. These current findings would appear to add support to the contention that quickness over short distances and agility are the elements that characterise soccer players and distinguish them from other athletes (Reilly et al., 2000).

The results of this study indicated significantly higher values of estimated $\dot{V}O_{2peak}$ in academy players in comparison to school pupils ($p<0.01$), a significant difference in estimated $\dot{V}O_{2peak}$ was found in each age group studied (U11 to U18) (Figure 9.1.7). For example, on average the U12 academy players estimated $\dot{V}O_{2peak}$ was 13.4 $ml.kg^{-1}.min^{-1}$ higher than the U12 school pupils. The current results are in accordance with the findings of Jankovic and colleagues (1993), who observed significantly higher values of $\dot{V}O_{2max}$ in 15 to 17 year old Croatian soccer players in comparison to the normal population of the same age span. In soccer a high $\dot{V}O_{2max}$ has been suggested to be a hallmark of well trained elite players (Reilly and Gilbourne, 2003). Furthermore, it has been proposed that consistent observations of $\dot{V}O_{2max}$ above 60 $ml.kg^{-1}.min^{-1}$ in elite teams implies a threshold below which an individual is unlikely to possess the physiological attributes to be successful in elite level contemporary soccer (Reilly et al., 2000). Based on these suggestions the comparatively higher $\dot{V}O_{2peak}$ values demonstrated by the academy players in the current study may be a product of their exposure to more systematic training and the inherent requirement to possess a high $\dot{V}O_{2peak}$ in order to be successful at the elite level.

When comparing club academy players and international academy players in the present study the only significant difference in terms of anthropometric, body shape and physical performance characteristics was the comparatively better RJ performance of the international academy players ($p<0.05$; Table 9.1.6). The lack of significant differences between the club academy players and international academy players would appear to support to some extent the findings of Le Gall and colleagues (2010) who compared former elite French academy players, including, 16 internationals, 56 professionals and 89 amateurs. Whilst differences were found to exist between the professionals and amateurs, no differences were apparent between internationals and professionals (Le Gall et al., 2010). Similarly, the present findings would suggest that with the exception of the RJ test, the anthropometric, body shape and physical performance characteristics examined here were not able to discriminate between players at the highest elite level.

The range of subjects in the present study, from non-soccer playing school pupils to international academy players has allowed comparisons across the full spectrum of abilities. The results of the study show that there is a progressive improvement in the physical capacities of young soccer players as the playing level increases from non-elite school pupils to elite English professional club academy players. However, few differences in physical performance were evident at the highest level between club academy players and international academy players. In summary, whilst a number of the anthropometric and physical performance variables were able to distinguish between different soccer ability groups, agility was found to be the key distinguishing characteristic.

9.1.4.1 Practical applications

The normative data and performance standards that have been established in this study from non-soccer players through to non-elite and elite young players will provide school teachers, coaches and sports scientists with an objective tool with which to benchmark any individuals' physical performance. The results of the present study also provide practitioners with evidence that agility is the key distinguishing characteristic of elite players, further supporting the process of talent identification in elite soccer.

9.2 RELEASED AND RETAINED ACADEMY PLAYERS: ANTHROPOMETRIC AND PHYSICAL PERFORMANCE CHARACTERISTICS

9.2.1 INTRODUCTION

Since 1997 and the introduction of the Football Associations 'Charter for Quality' (Wilkinson, 1997) soccer academies associated with professional clubs have been entrusted with the selection and development of elite young players in England. Within this soccer academy structure, coaches are continually looking for the best method to identify and develop elite young players (Stratton et al., 2005). Identifying talent in field-based team games is seen as far more complex than in individual sports which offer themselves more readily to objective measures of performance (Reilly et al., 2000).

Talent selection in soccer is viewed as an imprecise procedure because there are numerous external factors involved in the development of prospective players (Mujika et al., 2009). Despite this researchers have attempted to identify characteristics that can discriminate between elite and sub-elite players in an effort to guide talent selection (Reilly et al., 2000; le Gall et al., 2010; Nevill, Holder and Watts, 2009). Some of these studies have been focused on senior players. For example, Nevill, Holder and Watts (2009) sought to identify the key body size and shape characteristics associated with successful professional players. Subsequent analysis revealed successful players to be taller and more linear, as identified by a greater reciprocal ponderal index (RPI) and ectomorphy score.

Other studies have been based on younger developing players. Franks and colleagues (2002) aimed to identify characteristics that would distinguish between 64 English international youth soccer players aged 14 to 16 years who had, or had not, been offered a professional contract. Their analysis identified no significant differences in any of the anthropometric or physical performance characteristics recorded between the two groups of players. Conversely, Reilly and colleagues (2000) examining 16 elite and 15 sub-elite young players aged 15 to 16 years reported that a number of anthropometric and physical performance measures, including, body size (standing height and body mass), body composition (estimated percent body fat), somatotype, agility, sprint speed and aerobic power were able to discriminate between the two groups of players (Reilly et al., 2000). In the previous section (Chapter 9.1) it was reported that anthropometric (standing height, body mass, BMI, reciprocal ponderal index and ectomorphy) and physical performance (RJ; CMJ; CMJA; 10 m and 20 m sprint, agility and estimated $\dot{V}O_{2peak}$) variables distinguished between elite academy players and non-elite school pupils.

The purpose of this study was to identify anthropometric and physical performance characteristics in an extensive group of elite young players across a wide range of age groups and to determine whether such characteristics are able to define between successful (those retained) and unsuccessful (those released) players within the English professional soccer academy programme. Based on the limited earlier studies in the literature and the findings reported in the previous section (Chapter 9.1) it was hypothesized that retained players would have better physical performance characteristics than released players and that agility might distinguish best between retained and released players.

9.2.2 METHODS

9.2.2.1 Participants

Participant information is provided in section 3.3.4. At the end of each playing season during which the testing was conducted the participating clubs provided information in relation to which players were being released and retained for the following season (Table 9.2.1).

Estimated peak oxygen uptake ($\dot{V}O_{2peak}$) was measured in 727 subjects (94 released and 633 retained players) using the MSFT (Ramsbottom et al., 1988). A detailed description of the MSFT protocol can be found in section 3.4.5.

Table 9.2.1. Distribution of released vs. retained players by age group.

Age Group	Player Group (n)	
	Released	Retained
U9	42	141
U10	34	172
U11	48	188
U12	59	210
U13	25	223
U14	86	202
U15	39	213
U16	48	146
U17	5	131
U18	30	132
U19	28	50
Total (n)	444	1808
%	19.7	80.3

9.2.2.2 Procedures

A detailed description of the procedures and physical performance testing protocol can be found in sections 3.3 and 3.4.

Estimated peak oxygen uptake ($\dot{V}O_{2peak}$) was measured in 727 subjects (94 released and 633 retained players) using the MSFT (Ramsbottom et al., 1988). A detailed description of the MSFT protocol can be found in section 3.4.5.

9.2.2.3 Statistical analysis

Data were analysed using SPSS (Version 16.0, Chicago, Illinois, USA) and MLwiN (Version 2.16, Bristol, U.K.). Descriptive statistics were calculated. Two-way analysis of variance (ANOVA) was used to investigate differences in anthropometric and physical performance variables between the released and retained players, age groups and the interaction between released / retained and age. When a significant interaction released / retained*age was found post hoc pairwise bonferroni analysis by age group was conducted. Binomial logistic regression was used to compare the anthropometric and physical performance characteristics of the released and retained players. Statistical significance was accepted at the 95% confidence level ($p<0.05$). Values are reported as mean (±SD).

9.2.3 RESULTS

9.2.3.1 Anthropometric characteristics

The retained players were significantly taller than released players ($p<0.01$), with a significant interaction between released / retained and age in the U12 to U14 age groups ($p<0.01$; Table 9.2.2). Similarly, the retained players were significantly heavier than released players ($p<0.01$), with a significant interaction released / retained and age in the U13 and U14 age groups ($p<0.01$; Table 9.2.2). No significant difference in the body shape values (BMI, Reciprocal Ponderal Index, Ectomorphy) were found between the retained and released players, although some significant interactions between released / retained and age in the U12 to U14 age groups were observed ($p<0.05$; Table 9.2.3). The retained players were found to be significantly older than the released players ($p<0.01$), with a significant interaction between released / retained and age in the U9 to U16 age groups ($p<0.05$; Table 9.2.2). The binomial logistic regression analysis suggests that compared with released players, retained players were 1.02 times more likely to be taller ($p<0.05$; Table 9.2.4).

Table 9.2.2. Body size characteristics of released vs. retained players by age group (mean±SD).

Age Group (years)	Chronological Age (yrs)		Standing Height (cm)		Body mass (kg)	
	Released	Retained	Released	Retained	Released	Retained
U9	9.0±0.4	9.2±0.3*	134.1±6.0	135.5±5.2	30.1±3.5	31.0±3.7
U10	10.1±0.3	10.2±0.3*	140.2±5.1	140.2±5.7	34.5±3.7	34.0±4.4
U11	11.0±0.4	11.2±0.3*	145.4±6.8	145.2±6.8	38.4±5.7	37.4±5.4
U12	12.1±0.4	12.2±0.3*	148.8±6.8	152.3±7.5*	40.7±5.5	42.3±6.8
U13	13.0±0.4	13.2±0.3*	151.9±8.7	158.2±8.5*	43.8±7.2	47.3±8.1**
U14	14.0±0.3	14.2±0.3*	163.9±8.0	167.7±8.4*	51.5±8.3	57.2±9.0*
U15	15.0±0.3	15.2±0.4*	171.6±8.4	172.0±7.9	61.4±10.6	62.4±9.1
U16	15.9±0.3	16.1±0.4*	175.1±5.6	176.2±6.2	65.5±6.9	67.8±8.0
U17	17.0±0.3	17.2±0.4	177.5±12.9	178.0±6.4	71.2±15.5	70.7±7.5
U18	18.1±0.4	18.1±0.4	178.3±6.3	179.2±5.6	73.2±6.9	72.9±7.0
U19	19.1±0.3	19.0±0.3	177.7±6.5	180.2±4.5	74.5±7.8	76.1±6.9

Main effect released / retained, $p<0.01$; main effect age group, $p<0.01$; interaction released / retained*age, $p<0.05$, post hoc pairwise bonferonni analysis by age group, *$p<0.01$, **$p<0.05$.

Table 9.2.3. Body shape characteristics of released vs. retained players by age group (mean±SD).

Age Group (years)	BMI (kg.m^{-2})		RPI (cm.kg$^{-0.333}$)		Ectomorphy	
	Released	Retained	Released	Retained	Released	Retained
U9	16.7±1.4	16.9±1.3	43.2±1.4	43.2±1.2	3.0±1.0	3.1±0.9
U10	17.5±1.4	17.3±1.5	43.1±1.2	43.4±1.3	3.0±0.9	3.2±0.9
U11	18.1±1.7	17.6±1.6	43.2±1.3	43.6±1.3	3.1±0.9	3.3±0.9
U12	18.3±1.8	18.1±1.6	43.4±1.5	43.9±1.2**	3.2±1.1	3.5±0.9
U13	18.9±2.0	18.7±1.8	43.2±1.6	43.9±1.3**	3.1±0.9	3.6±1.0**
U14	19.1±1.8	20.2±1.8*	44.2±1.2	43.7±1.3*	3.8±0.9	3.4±0.9*
U15	20.7±2.1	21.0±1.9	43.7±1.2	43.5±1.3	3.4±0.9	3.3±0.9
U16	21.3±1.7	21.8±1.8	43.5±1.2	43.3±1.2	3.3±0.9	3.1±0.9
U17	22.3±1.8	22.3±1.5	43.0±0.3	43.1±1.0	2.9±0.2	3.0±0.7
U18	23.0±1.6	22.7±1.7	42.7±1.1	43.0±1.2	2.7±0.8	2.9±0.9
U19	23.6±1.9	23.4±1.8	42.3±1.3	42.6±1.1	2.4±0.9	2.6±0.8

Main effect released / retained, NS; main effect age group, $p<0.01$; interaction released / retained*age, $p<0.01$, post hoc pairwise bonferonni analysis by age group, *$p<0.01$, **$p<0.05$.

9.2.3.2 Physical performance characteristics

Vertical jump performance (RJ; CMJ; CMJA) of the retained players was significantly better in comparison to that of the released players ($p<0.01$; Figure 9.2.1). Some of the biggest differences in vertical jump performance between the released and retained players were observed in the U19 age group where retained players jumped 3.8 cm, 3.9 cm and 3.7 cm higher than the released players in the RJ, CMJ and CMJA, respectively (Figure 9.2.1).

Similarly, both sprint (10 m and 20 m) and agility performance of the retained players was significantly faster in comparison to the released players ($p<0.01$; Figure 9.2.2). Some of the biggest differences in sprint and agility performance between the released and retained players were observed in the U11, U10 and U17 age groups where retained players were 0.05 s, 0.12 s and 0.36 s faster than the released players in the 10 m sprint, 20 m sprint and agility test, respectively (Figure 9.2.1). Such differences would equate to the U11, U10 and U17 retained players being 0.30 m, 0.65 m and 1.70 m ahead of the released players on the 10 m sprint, 20 m sprint and agility test, respectively. Estimated $\dot{V}O_{2peak}$ was also found to be significantly higher in the retained players as opposed to the released players ($p<0.01$; Figure 9.2.3).

The binomial logistic regression analysis suggests that compared with released players, retained players were 1.54 and 1.95 times more likely to be faster over a 10 m sprint and agility test, respectively ($p<0.05$; Table 9.2.4). The analysis also suggests that retained players were 1.03 times more likely to jump higher when performing the CMJA ($p<0.05$; Table 9.2.4).

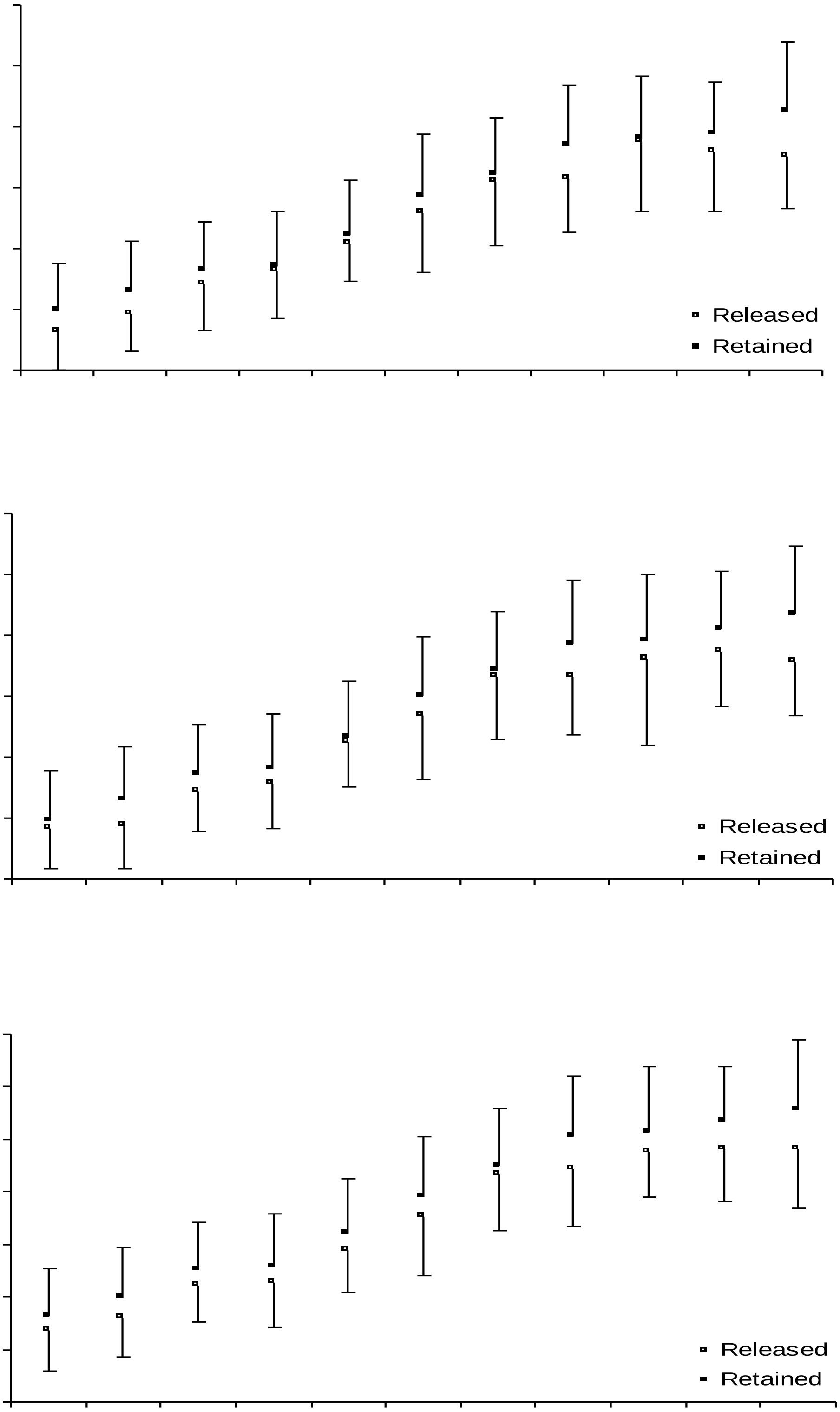


Figure 9.2.1. Vertical jump performance of released vs. retained players by age group (mean±SD).
Main effect released / retained, p<0.01; main effect age group, p<0.01; interaction released / retained*age, NS.

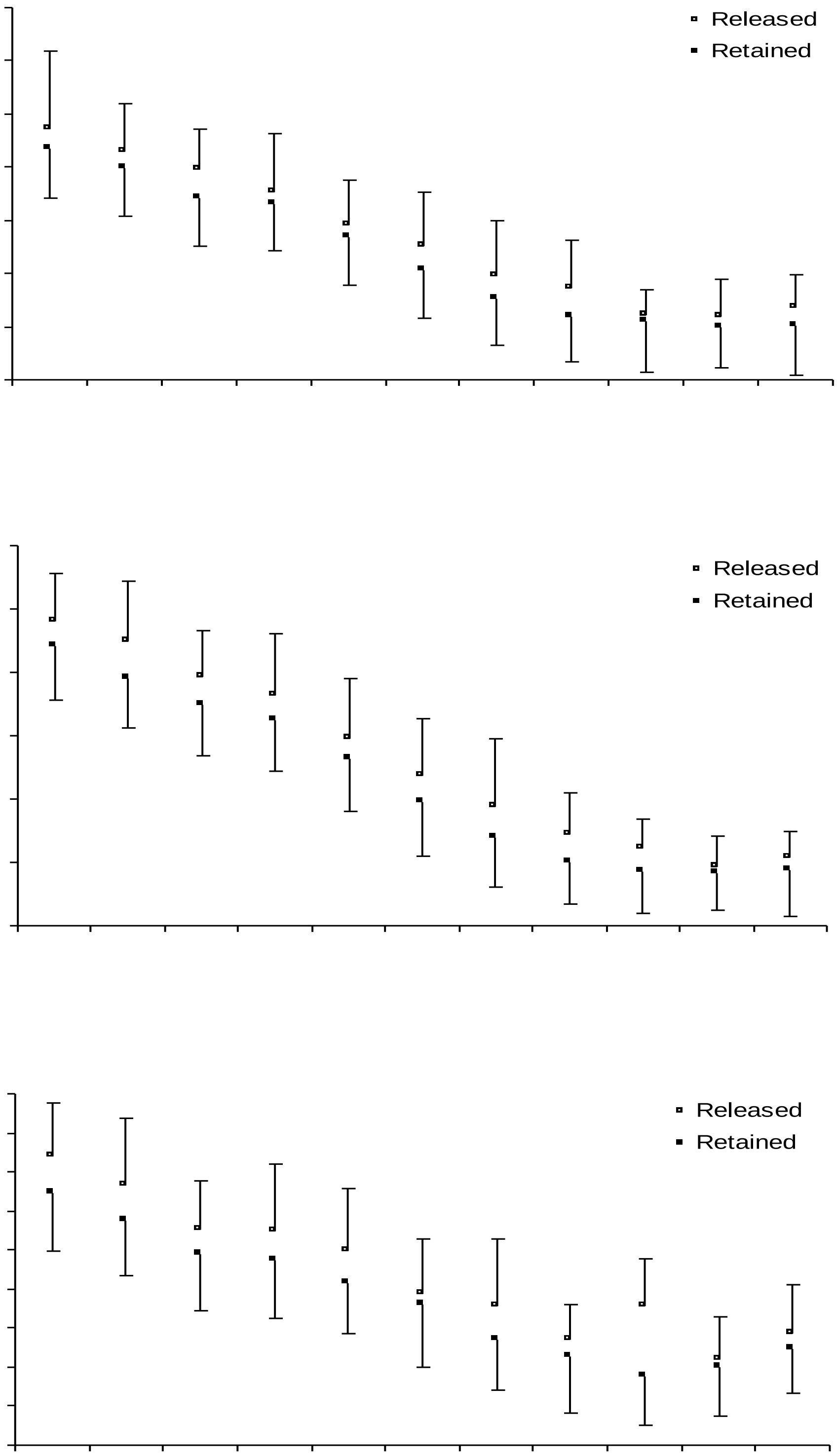


Figure 9.2.2. Sprint and agility performance of released vs. retained players by age group (mean±SD).
Main effect released / retained, p<0.01; main effect age group, p<0.01; interaction released / retained*age, NS.

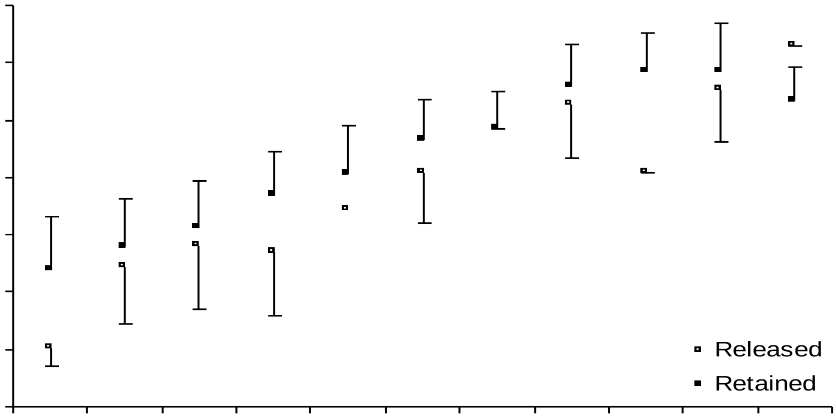


Figure 9.2.3. $\dot{V}O_{2peak}$ values of released vs. retained players by age group (mean±SD).
Main effect released / retained, $p<0.01$; main effect age group, $p<0.01$; interaction released / retained*age, NS.

Table 9.2.4. Binomial logistic regression analysis of released vs. retained players.

Variable	ß	SE	Odds Ratio ($e^{ß}$)	Lower 95%CI	Upper 95%CI	Probability
Intercept	1.515**	0.095				
Age	-0.266**	0.048	0.77	0.70	0.84	0.777
Height	0.017**	0.007	1.02	1.00	1.03	0.822
10m Speed	0.434**	0.19	1.54	1.06	2.24	0.875
Agility Speed	0.666**	0.171	1.95	1.39	2.72	0.899
CMJA	0.026**	0.011	1.03	1.00	1.05	0.824

**$p<0.05$

9.2.4 DISCUSSION

The present study has demonstrated that a number of anthropometric and physical performance variables distinguish retained from released academy players. The key findings being that in comparison to released players the retained players were taller, had higher CMJA and were faster on the 10 m sprint and agility tests ($p<0.05$; Table

9.2.4).

An initial finding of this study indicated that retained players were older than those players who were released ($p<0.01$), this was found to be significant in the U9 to U16 age groups ($p<0.01$; Table 9.2.2). The retention of players who are chronologically older may have contributed to the result that retained players were significantly taller than released players ($p<0.01$; Figure 9.2.2). Indeed, the binomial logistic regression analysis suggests that compared with released players, retained players were slightly (1.02 times) more likely to be taller ($p<0.05$; Table 9.2.4). This finding supports previous suggestions that height is both an important criterion in talent selection (Gil et al., 2008; le Gall et al., 2010) and for success in professional soccer (Nevill, Holder and Watts, 2009). It should be noted that not all studies have found significant differences in standing height to exist between players who were considered either successful or unsuccessful. For example, Franks and colleagues (2002) found no significant differences in standing height between young players who signed professional contracts and those who did not. However the authors suggest that the use of historical data in their study may have contributed to no significant differences being observed given the associated problems concerning reliability and accuracy of measurement. In a study of 50 non-elite 14 year old Spanish players Gil and colleagues (2003) found that players selected to play in the main team were taller than those who were not selected (172.0 cm vs. 165.0 cm). Nevill, Holder and Watts (2009) suggested that apart from the fact that taller players are likely to be more successful when heading the ball both in attack and defence, their relatively longer legs will be advantageous when closing down and tackling opposition players. Suggestions of this nature may partly explain why taller players are more likely to be retained in professional English soccer academies. For example, in the U13 age group retained players were found to be on average 6.3 cm taller than those players who were released (Table 9.2.2). The selection of taller players at an early age has been observed in other sports were height may be perceived as an advantage, including, Australian Rules Football in the U18 age group (Keogh, 1999) and 10 year old Rugby Union players (Pienaar, Spamer and Steyn, 1998).

Similar to the differences observed in standing height between retained and released players, retained players were found to be significantly heavier than released players particularly in the U13 ($p<0.05$) and U14 ($p<0.01$) age groups (Table 9.2.2). This supports the earlier findings of Jankovic, Heimer and Matkovic (1993) who found that successful Croatian players aged 15 to 17 years were both taller and heavier than there less successful counterparts. More recently it has been suggested that body mass, whether in absolute terms or relative to height^2 (BMI) is less of an important determinant in the selection of successful professional soccer players (Nevill, Holder and Watts, 2009). However, the current finding that retained players were significantly heavier than released players in the U13 and U14 age groups would suggest that body mass in absolute terms is an important determinant in the selection of successful elite young soccer players.

No significant difference in body shape characteristics (BMI, RPI and Ectomorphy) between released and retained players was found (Table 9.2.3). Nevill, Holder and Watts (2009) have recently suggested that more successful professional soccer players are becoming taller and more linear. They identified the RPI as the key height-to-mass or shape parameter associated with successful professional players, with 97% (449 out of the 462 players studied) having a RPI > 40.74. Similarly, in relation to elite young soccer players our results found 99% and 97% of the retained and released players to have an RPI >40.74, respectively. Furthermore, the slightly higher ectomorphy score of the U19 players who were retained (2.6±0.8) compared to those who were released (2.4±0.9) (Table 9.2.3), is more comparable to the score of 2.7 reported for senior professional players (Nevill, Holder and Watts, 2009).

Vertical jump performance (RJ; CMJ; CMJA) was significantly higher in the retained players compared to those players who were released ($p<0.01$; Figure 9.2.1). Binomial logistic regression analysis also suggests that when compared with released players, the retained players were 1.03 times more likely to jump higher when performing the CMJA ($p<0.05$; Table 9.2.4). Similar results were observed by Gil and colleagues (2007) where vertical jump performance was found to discriminate between selected and non-selected players. Based on this finding the authors suggested that power of the lower extremities measured by vertical jump performance was one of the most important factors in the selection process for defensive and forward players. Le Gall and colleagues (2010) also suggest that jumping capacity may discriminate between players who are successful or not in achieving the highest standards of play. The present results are in support of these previous observations, further suggesting that vertical jump assessment can provide important information which may be useful for the purpose of player selection. In relation to this Stolen and colleagues (2005) suggest that it may be reasonable to expect that the elite soccer player has a vertical jump height value close to 60 cm.

Sprint tests have been described as an important element in the evaluation of soccer players (Svensson and Drust, 2005). In the present study the retained players were found to be significantly faster over 10 m and 20 m in comparison to those players who were released ($p<0.01$; Figure 9.2.2). For example, the U10 retained players were on average 0.12 s faster than the released players on a 20 m sprint, which equates to being 0.65 m ahead (Figure 9.2.2). Furthermore, the binomial logistic regression analysis suggests that compared with released players, retained players were 1.54 times more likely to be faster over a 10 m sprint ($p<0.05$; Table 9.2.4). Being faster than an opponent over a 10 m sprint can be crucial given that the ability to accelerate can often decide the outcome of games (Svensson and Drust, 2005). Previously in a comparatively smaller study of 16 elite and 15 sub-elite 16 year old players, the elite players were found to be faster over 15 m, 25 m and 30 m (Reilly et al, 2000). Although, it was noted that sprint time over the shorter distance of 15 m was the strongest discriminator between the elite and sub-elite players. Similarly, other studies have observed that sprint speed over short distances (10 m to 30 m) can be used to distinguish between elite and sub-elite senior players (Kollath and Quade, 1993; Cometti et al., 2001). The results of the present study further emphasise the relative importance for elite players to possess the ability to accelerate quickly. These observations would suggest that sprint tests over short distances should form an integral part in the physical evaluation of soccer players. The information from such tests can then be used to add an element of objectivity to the selection process of elite young soccer players.

It has been reported that an agility test can discriminate elite soccer players from the general population better than any other field test of physical performance (Raven et al., 1976). The same authors concluded that a players agility was their greatest asset which distinguished them from the normal population. The results of the present study would appear to support this earlier suggestion, as the retained players were found to be significantly faster on the agility test than those players who were released ($p<0.01$; Figure 9.2.2). For example, on average the U17 retained players were 0.36 s faster than their released counterparts over the 20.8 m agility test which equates to being 1.70 m ahead (Figure 9.2.2). The binomial logistic regression analysis further suggests that retained players were 1.95 times more likely to be faster over the agility test than released players ($p<0.05$; Table 9.2.4). Reilly and colleagues (2000) also suggested that agility was the most powerful discriminator between elite and sub-elite players. Our results confirm these earlier observations referring to the importance of agility testing in soccer players. It would appear that in order to construct an accurate physical profile of a soccer player an appropriate test of the player's agility is vital.

The estimated $\dot{V}O_{2peak}$ of the retained players was found to be significantly higher than those players who were released ($p<0.01$; Figure 9.2.3). Previous research has suggested that $\dot{V}O_{2max}$ is a useful tool to discriminate between different standards of players (Wisloff, Helgerud and Hoff, 1998). Similarly, Jankovic, Heimer and Matkovic (1993) reported that young Croatian players who went on to play national as opposed to regional level soccer possessed better aerobic power. Furthermore, it has been suggested that the consistent observation of $\dot{V}O_{2max}$ values above 60 $ml.kg^{-1}.min^{-1}$ in elite players could infer a threshold below which an individual player may not possess the physiological attributes to be successful in elite level soccer (Reilly, Bangsbo and Franks, 2000). Maximal oxygen uptake has also been reported to be positively related to the total amount of work done during games (Hoff et al., 2002). These associated performance benefits of possessing a higher $\dot{V}O_{2peak}$ may explain the finding of higher estimated $\dot{V}O_{2peak}$ values in the retained players in the current study.

The battery of field tests used in this investigation was convenient for use with squads of players in the professional soccer club setting. This enabled the study to be the largest of its kind to date, with data being collected on 2252 elite young players. The results demonstrate that a battery of anthropometric and physical performance measures can discriminate among players who have previously been selected and exposed to systematized training at the elite level. The variable best able to distinguish between retained and released academy players was agility.

9.2.4.1 Practical applications

The present study highlights to practitioners the relative importance of physical performance testing as a tool to assist with the ongoing process of talent identification within an elite soccer academy environment. The study also presents practitioners with a valid and reliable test of agility which has been shown to be the most sensitive measure for distinguishing between successful (retained) and unsuccessful (released) elite young players.

9.3 COACH ASSESSED PLAYING ABILITY GROUPS: ANTHROPOMETRIC AND PHYSICAL PERFORMANCE CHARACTERISTICS

9.3.1 INTRODUCTION

Talent identification in field-based team games is viewed as being far more complex than in individual sports which offer themselves more readily to objective measures of performance (Reilly et al., 2000). In team games like soccer the prediction of long term success in young players is difficult because of the multidimensional qualities that are required. Despite these inherent complexities soccer coaches are continually looking for the best method to identify and develop elite young players (Stratton et al., 2005). In England the introduction of the Football Associations ‘Charter for Quality’ in 1997 (Wilkinson, 1997) established the framework in which soccer academies associated with professional clubs became the focus for the selection and development of elite young English players.

Mujika and colleagues (2009) have recently suggested that talent selection in soccer is an imprecise procedure because of the numerous external factors involved in the development of prospective players. This may explain why talent identification programmes in soccer are not firmly grounded on any scientific rationale (Reilly et al., 2000). Attempts to generate scientific observations to compliment the subjective judgements made on talented young players has seen researchers endeavouring to identify characteristics that can discriminate between elite and sub-elite players in an effort to support the process of talent selection (Reilly et al., 2000; le Gall et al., 2010; Nevill, Holder and Watts, 2009).

Thus the purpose of the present study was to identify anthropometric and physical performance characteristics of elite young players placed in different ability groups on the basis of the subjective ratings of players ‘global soccer ability’ as determined by experienced coaches within the English professional soccer academy programme. The hypothesis to be tested was that anthropometric and physical performance characteristics could distinguish between elite young players placed different ability groups on the basis of coach opinion.

9.3.2 METHODS

9.3.2.1 Participants

A total of 771 elite child and adolescent soccer players (age 13.8±2.8 years; height 160.8±16.2 cm; body mass 52.4±16.0 kg) participated in this study. All the subjects were registered at one of six professional soccer club academies in England.

Estimated peak oxygen uptake ($\dot{V}O_{2peak}$) was measured in 610 subjects using the MSFT (Ramsbottom et al., 1988). A detailed description of the MSFT protocol can be found in section 3.4.5.

9.3.2.2 Participant information

Prior to each testing session the coaches scored each player in relation to their 'global soccer ability' (1 – above average for academy age group (n=198); 2 - average for academy age group (n=485); 3 – below average for academy age group (n=88)). The professional playing status of 236 participants who were over 18 years of age at the end of the 2007/2008 playing season (11.05.08) was sourced from the International Soccer Bank (Neustadt, Germany).

9.3.2.3 Procedures

A detailed description of the procedures and physical performance testing protocol can be found in sections 3.3 and 3.4.

9.3.2.4 Statistical analysis

Data were analysed using SPSS (Version 16.0, Chicago, Illinois, USA) and MLwiN (Version 2.16, Bristol, U.K.). Descriptive statistics were calculated. Two-way analysis of variance (ANOVA) was used to investigate differences in anthropometric and physical performance variables between the different playing ability groups ('above average'; 'average'; 'below average'), age groups and the interaction between ability group and age. When a significant interaction ability group*age was found post hoc pairwise bonferroni analysis by age group was conducted. Binomial logistic regression was used to compare the anthropometric and physical performance characteristics of the different playing ability groups ('below average' vs. 'average' and ‘average’ vs. ‘above average’). Statistical significance was accepted at the 95% confidence level ($p<0.05$). Values are reported as mean (±SD).

9.3.3 RESULTS

9.3.3.1 Ability group characteristics

The majority of the players assessed by their academy coaches were classified as being ‘average’ (62.9%), with 25.7% and 11.4% being ‘above average’ and ‘below average’, respectively (Table 9.3.1). Out of the 236 participants who were over 18 years of age at the end of the 2007/2008 playing season 26.3% had gained professional contracts. Most of the players who gained professional contracts (61.3%) had previously been classified as ‘above average’ by their academy coaches as opposed to ‘below average’ players who only constituted 2% of the professional players (Figure 9.3.1).

Table 9.3.1. Distribution of players in relation to ability groups and age groups.

	Ability Group (n)			Total (n)
Age Group	Above Average	Average	Below Average	
U9	11	48	9	68
U10	26	47	7	80
U11	23	54	5	82
U12	20	75	12	107
U13	16	68	12	96
U14	23	59	14	96
U15	26	43	11	80
U16	21	35	6	62
U17	15	34	8	57
U18	17	22	4	43
Total (n)	198	485	88	
%	25.7	62.9	11.4	
Chronological Age (years)	13.7±2.8	13.2±2.6	13.4±2.6	

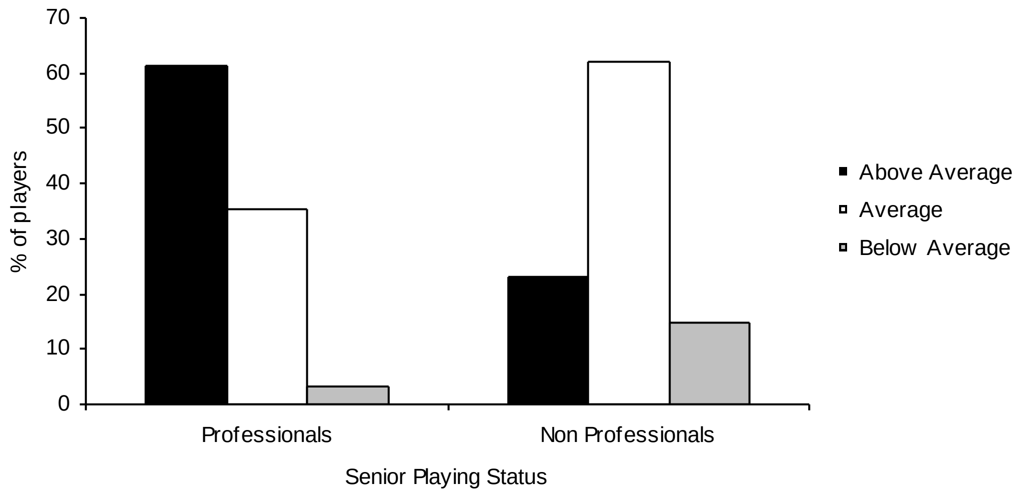


Figure 9.3.1. Senior playing status in relation to ability groups.

9.3.3.2 Anthropometric characteristics

No significant difference in standing height or body mass were found between ability groups (Table 9.3.2). A significant interaction ability group*age was found in body mass ($p<0.05$; Table 9.3.2) with 'above average' players being heavier than 'below average' players in the U14 and U18 age groups ($p<0.05$; Table 9.3.2). No significant difference in the body shape values (BMI, Reciprocal Ponderal Index, Ectomorphy) were found between ability groups.

Table 9.3.2. Anthropometric characteristics of players in relation to ability groups and age groups (mean±SD).

Age Group (years)	Standing Height (cm)		
	Above Average	Average	Below Average
U9	136.7±5.1	133.4±5.4	134.6±3.6
U10	138.9±5.6	140.0±5.9	141.6±5.2
U11	145.3±7.4	142.8±5.5	146.4±4.0
U12	154.0±7.0	151.4±7.3	151.4±7.1
U13	157.0±8.0	156.9±8.5	156.5±7.2
U14	170.5±8.5	166.5±9.3	164.0±9.2
U15	173.8±7.1	173.2±8.4	173.2±11.5
U16	176.1±5.7	176.8±6.5	172.3±4.3
U17	176.8±4.6	178.5±7.4	175.4±6.9
U18	178.0±5.1	179.4±5.7	184.7±2.5
Age Group (years)	Body mass (kg)		
	Above Average	Average	Below Average
U9	30.7±4.1	29.8±4.0	30.5±4.7
U10	33.2±4.4	34.2±4.6	33.5±2.9
U11	37.2±4.4	36.2±4.5	40.4±1.3
U12	42.4±6.4	42.0±7.4	43.0±4.6
U13	46.1±7.8	45.9±8.1	48.2±9.6
U14	60.8±10.1	56.2±8.5	52.0±8.1[a**]
U15	65.2±7.6	63.6±9.9	62.4±11.4
U16	68.8±7.5	69.0±7.8	62.6±5.5
U17	72.0±5.8	71.3±7.7	67.1±8.9
U18	72.2±6.2	73.8±6.3	81.0±7.5[a**]

Main effect ability group, NS; post hoc pairwise bonferonni analysis by ability group, [a]significantly different to 'above average' players, *p<0.01, **p<0.05; main effect age group, p<0.01; interaction ability group*age, standing height, NS, body mass, p<0.05.

9.3.3.3 Physical performance characteristics

'Above average' players were found to perform significantly better on the vertical jump tests (RJ; CMJ; CMJA) in comparison to 'average' and 'below average' players (p<0.01; Figure 9.3.2). For example, on the rocket jump U17 'above average' players jumped 3.9 cm (9.3 %) higher than 'average' players, 41.8 ± 7.3 cm vs. 37.9 ± 4.2 cm, respectively (Figure 9.3.2). The interaction ability group*age was not significant on the vertical jump tests (RJ; CMJ; CMJA). On the sprint tests (10 m; 20 m; agility) the 'above average' players were significantly faster than the 'average' and 'below average' players (p<0.01; Figure 9.3.3). For example, on the agility test U15 'above average' players were 0.36 s faster than 'below average' players, 4.11 ± 0.19 s vs. 4.47 ± 0.48 s, respectively (Figure 9.3.3). Such a difference would equate to 'above average' players being 1.68 m ahead of the 'below average' players on the 20.8 m agility test. The interaction ability group*age was not significant on the sprint tests (10 m; 20 m; agility). Estimated $\dot{V}O_{2peak}$ was also found to be significantly higher in the 'above average' players in comparison to the 'average' and 'below average' players ($p<0.01$; Figure 9.3.4). The interaction ability group*age was significant in relation to estimated $\dot{V}O_{2peak}$ ($p<0.01$; Figure 9.3.4). The binomial logistic regression analysis suggests that 'average' players were 2.28 times more likely to be faster on the agility test than 'below average' players ($p<0.05$; Table 9.3.3). The only discernable difference, when 'average' and 'above average' players were compared, was that 'above average' players were 1.04 times more likely to jump higher on the RJ ($p<0.05$; Table 9.3.4).

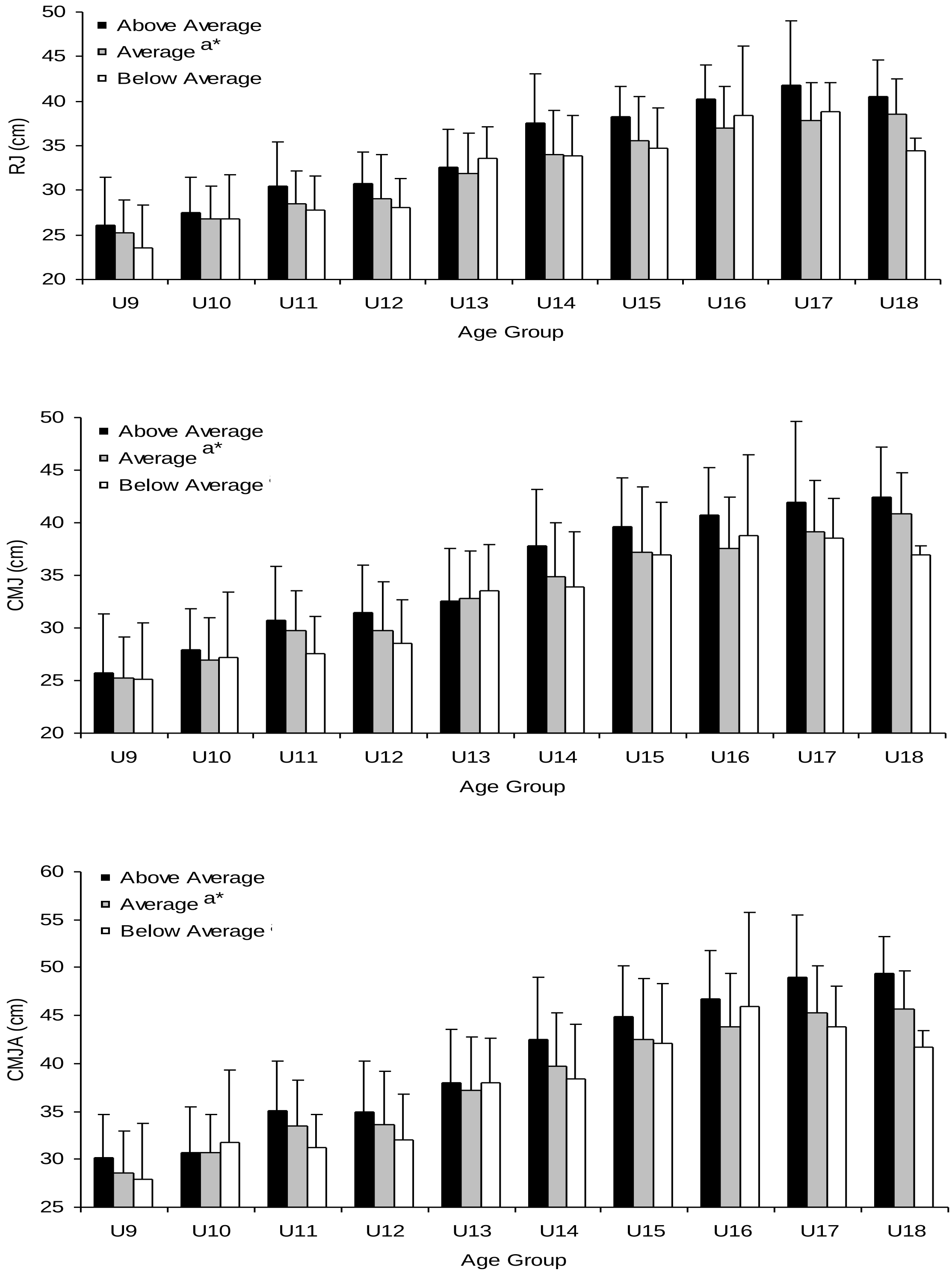


Figure 9.3.2. Vertical jump performance of players in relation to ability groups and age groups (mean±SD).
Main effect ability group, $p<0.01$; post hoc pairwise bonferonni analysis by ability group, [a]significantly different to 'above average' players, *$p<0.01$, **$p<0.05$; main effect age group, $p<0.01$; interaction ability group*age, NS.

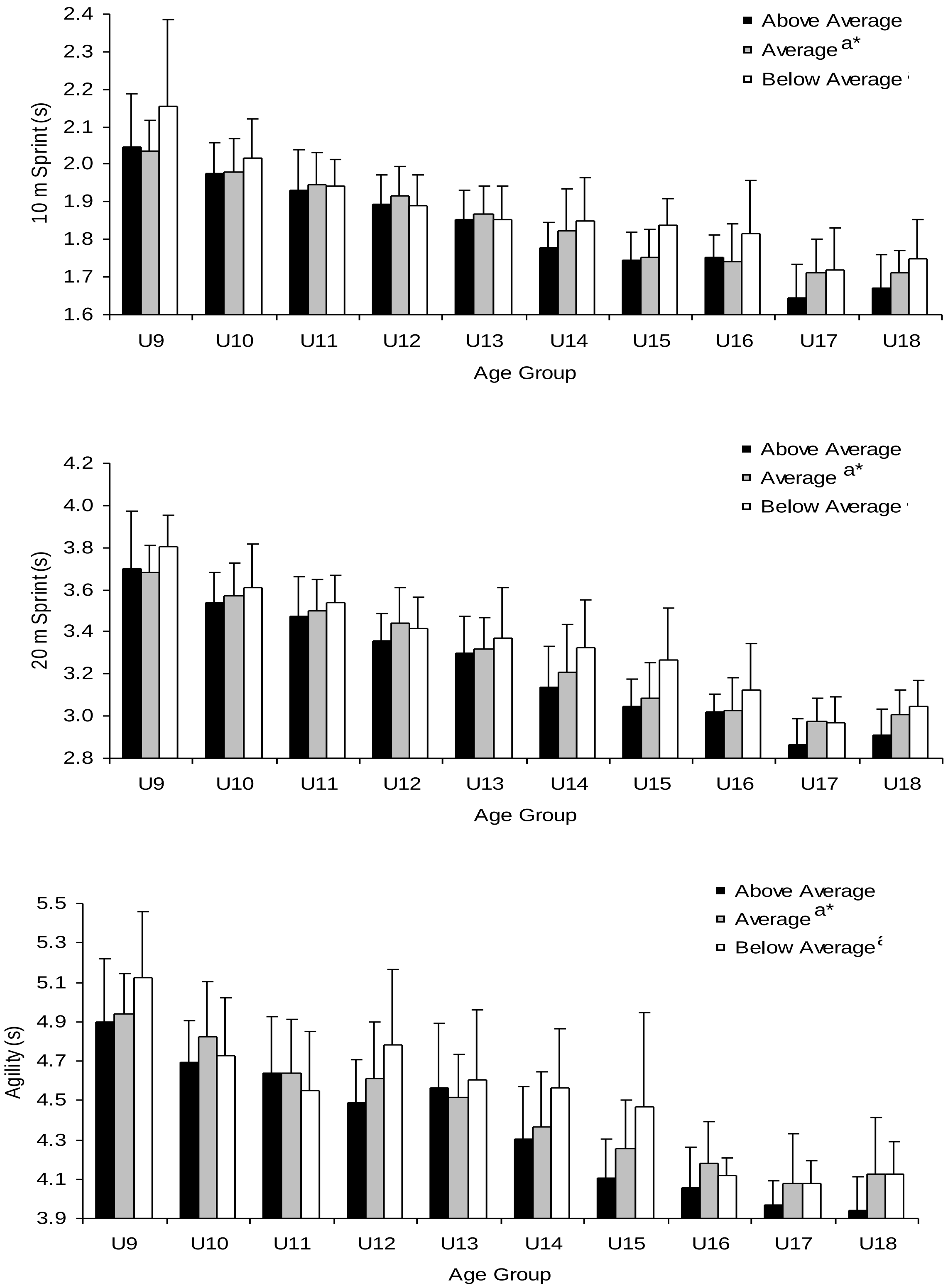


Figure 9.3.3. Sprint and agility performance of players in relation to academy ability groups and age groups (mean±SD).
Main effect ability group, $p<0.01$; post hoc pairwise bonferonni analysis by ability group, [a]significantly different to 'above average' players, *$p<0.01$, **$p<0.05$; main effect age group, $p<0.01$; interaction ability group*age, NS.

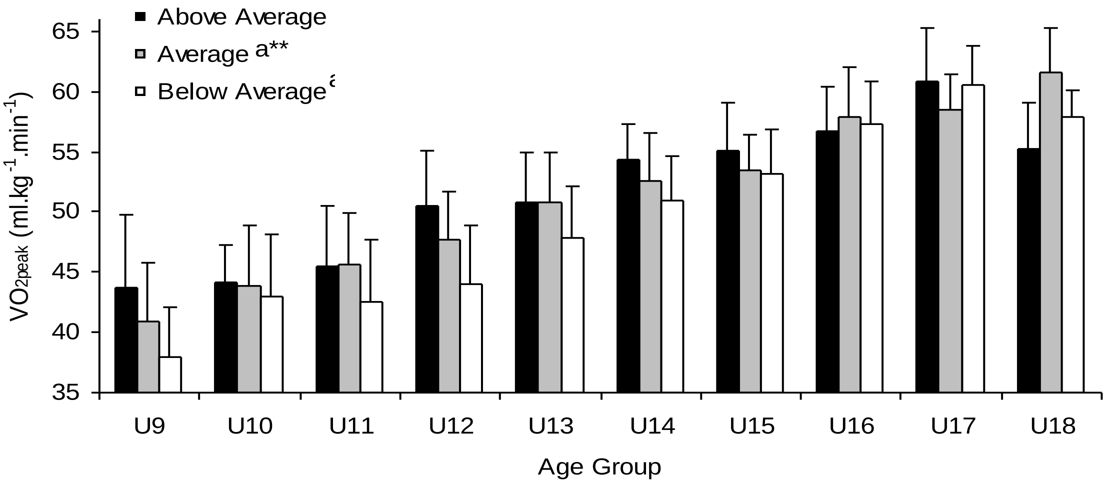


Figure 9.3.4. Estimated $\dot{V}O_{2peak}$ of players in relation to ability groups and age groups (mean±SD).
Main effect ability group, $p<0.01$; post hoc pairwise bonferonni analysis by ability group, [a]significantly different to 'above average' players, *$p<0.01$, **$p<0.05$; main effect age group, $p<0.01$; interaction ability group*age, $p<0.01$.

Table 9.3.3. Binomial logistic regression analysis of 'below average' vs. 'average' players.

Variable	ß	SE	Odds Ratio ($e^{ß}$)	Lower 95%CI	Upper 95%CI	Probability
Intercept	1.773**	0.129				
Age	-0.143**	0.058	0.87	0.77	0.97	0.836
Agility Speed	0.822**	0.329	2.28	1.19	4.34	0.931

**p<0.05

Table 9.3.4. Binomial logistic regression analysis of 'average' vs. 'above average' players.

Variable	ß	SE	Odds Ratio ($e^{ß}$)	Lower 95%CI	Upper 95%CI	Probability
Intercept	-0.888 *	0.117				
Rocket	0.044 *	0.012	1.04	1.02	1.07	0.301

**p<0.05

9.3.4 DISCUSSION

The majority of the studies on the relationship between anthropometric and physical performance characteristics and level of performance have compared elite with non-elite players (Jankovic et al., 1993; Janssens et al., 1998; Malina et al., 2000; Reilly et al., 2000). It has since been suggested that to gain more of an insight into the characteristics of elite players that the focus should be on talented young players who have already been detected (Elferink-Gemser, 2004). In line with this suggestion the present study has attempted to identify characteristics of different ability groups of elite young players in professional English Soccer Academies. The groups which form the basis of the comparisons were determined by the academy coaches' assessments of players 'global soccer ability'. The results of the study show that the majority of the players (62.9%) were classed as being 'average' for their academy age group (Table 9.3.1). Only 11.4% of the players were viewed as being 'below average' whilst 25.7% were reported to be 'above average' for their academy age group (Table 9.3.1).

Clearly not all the young elite soccer players selected for professional English soccer academies will progress into the senior professional game. One cannot predict with certainty which elite young players will go onto become professional players. In the context of the present study coaches were asked to classify players in terms of their 'global soccer ability', which is ultimately a product of several physical, technical, tactical, psychological and social factors. It was hypothesized that those players who the coaches classed as being 'above average' for their age group were more likely to progress into the professional ranks than those players classed as 'average' and 'below average'. It should be noted that the coaches involved in the study were highly qualified and experienced, working with the academy players in question throughout the season during both training and games. As we may have anticipated the results indicated that 61.3% of those players who went on to gain professional contracts were previously classed as being 'above average' by their academy coaches (Figure 9.3.1). This finding suggests that even at an early age some players begin to display certain characteristics to coaches that signify their capability to progress into the senior professional game. The finding that 77% of those players who failed to gain a professional contract were classed as being either 'average' (62.1%) or 'below average' (14.9%) further underlines this suggestion (Figure 9.3.1). However, it is interesting to note that 2% of those players who gained professional contracts had previously been viewed as 'below average' by their academy coaches (Figure 9.3.1). This fact is a reminder of the difficulties involved with predicting long term success in young players, a factor previously emphasized by Reilly and colleagues (2000).

No significant difference in standing height or body mass was found between the player ability groups (Table 9.3.2). Furthermore, no significant differences were observed between the player ability groups in terms of body shape parameters, including, BMI, reciprocal ponderal index and ectomorphy scores. These findings contrast with those of Nevill and colleagues (2009) who suggested that successful professional players are becoming taller and more linear, identifying the reciprocal ponderal index as the key height-to-mass ratio or shape parameter associated with successful professional players. However, when making comparisons with the results reported by Nevill and colleagues (2009) it must be taken into account that their observations were based on the analysis of historical data of senior players.

Unlike the anthropometric measures, the physical performance tests implemented in the present study were found to discriminate between the 'above average' players and the 'average' and 'below average' players. Vertical jump performance (RJ; CMJ; CMJA) was significantly higher in the 'above average' players ($p<0.01$; Figure 9.3.2). For example, in the CMJA 'above average' players jumped 3.2cm (7.9%) higher than both the 'average' and 'below average' players (Figure 9.3.2). Indeed, 'above average' players were 1.04 times more likely to jump higher on the RJ than 'average' players ($p<0.05$; Table 9.3.4). Markovic and colleagues (2004) have previously concluded that RJ and CMJ are the most reliable and valid field tests for the estimation of explosive power of the lower limbs in physically active men. Our findings would further suggest that RJ, CMJ and CMJA are sensitive enough to discriminate between young soccer players at the elite level. The finding that the 'above average' players exhibited the best vertical jump performances would support previous suggestions that explosive power, particularly in the lower extremities is an important attribute in the profile of an elite soccer player (Leatt, Shephard and Plyley, 1987; Faina et al., 1988). Furthermore, to highlight this point Arnason and colleagues (2004) reported a positive relationship between jumping height and team success, concluding that more attention should be given to vertical jump and power training in soccer players.

The ‘above average’ players better vertical jump performance was duplicated with significantly faster times on the 10 m and 20 m sprint tests in comparison to the ‘average’ and ‘below average’ players ($p<0.01$; Figure 9.3.3). For example, in the U17 age group the ‘above average’ players were 0.11 s faster than the ‘average’ and ‘below average’ players’ on the 20 m sprint which would equate to being 0.77 m ahead. This finding supports previous studies which have reported senior professional players to be significantly faster than their amateur counterparts when sprinting over short distances (Kollath and Quade, 1993; Cometti et al., 2001). Based on such observations it has been suggested that sprint ability over short distances may be a precondition for professional players, often proving crucial in the critical duels that influence the results of games (Reilly, Bangsbo and Franks, 2000; Stolen et al., 2005).

In relation to sprint ability, agility performance has been suggested as a physical performance prerequisite in soccer, given that players are frequently involved in rapid directional changes in order to be effective during a game (Reilly, Bangsbo and Franks, 2000). In the present study the agility performance of the ‘above average’ players was significantly faster than the ‘average’ and ‘below average’ players ($p<0.01$; Figure 9.3.3). For example, in the U15 age group the ‘above average’ players were 0.36 s faster than the ‘below average’ players on the agility test (Table 9.3.4). To be 0.36 s faster over the 20.8 m agility test would result in the ‘above average’ players being 1.68 m ahead of the ‘below average’ players in the U15 age group. It was also found that ‘average’ players were 2.28 times more likely to be faster on the agility test than ‘below average’ players ($p<0.05$; Table 9.3.3). These findings support the suggestion that elite players should possess the ability to change direction quickly (Reilly et al., 2000). Indeed, Reilly and colleagues (2000) found that agility performance was the most powerful discriminator between elite and sub-elite 15-16 year old players. Prior to this Raven and colleagues (1976) reported that an agility test distinguished professional soccer players from the normal population better than other field tests of strength, power and flexibility. However, within the discussion one should note the differences in the tests used in the various studies to assess agility. The test employed by Reilly and colleagues (2000) involved a 40 m sprint with turns, almost twice the 20.8 m distance of the agility test used in the present study. It has been reported that 96% of sprint bouts during a game of soccer are shorter than 30 m (Valquer, Baros and Santanna, 1998) therefore the shorter agility test used in this study would appear to be a more valid test for use with soccer players on which conclusions on the relative importance of agility in soccer may be established.

Estimated $\dot{V}O_{2peak}$ was the final physical performance measure adopted in the present study was also found to be significantly higher in the 'above average' players in comparison to the 'average' and 'below average' players ($p<0.01$; Figure 9.3.4). However, the significant interaction ability group*age ($p<0.01$) also revealed that in the U18 age group estimated $\dot{V}O_{2peak}$ values of 'average' players (61.5±3.7 $ml.kg^{-1}.min^{-1}$) were significantly higher than 'above average' players (55.2±3.9 $ml.kg^{-1}.min^{-1}$) in the U18 age group (Figure 9.3.4). This finding contrasts with previous studies which have reported higher VO_{2max} values in elite players when compared to sub-elite players (Jankovic et al., 1993; Reilly et al., 2000). Indeed it has previously been suggested that the consistent reports of VO_{2max} values above 60 $ml.kg^{-1}.min^{-1}$ in elite players may imply a threshold below which an individual player is unlikely to possess the physiological attributes for success in elite level soccer (Reilly, Bangsbo and Franks, 2000). More recently it has been suggested that given the game related performance advantages of a high level of VO_{2max} in soccer that it may be reasonable to expect VO_{2max} values of approximately 70 $ml.kg^{-1}.min^{-1}$ for a 75 kg professional player (Stolen et al., 2005). Given the fact that the estimated $\dot{V}O_{2peak}$ values of the 'above average' players is considerably below this value put forward by Stolen and colleagues (2005) and the fact that no significant differences were found to exist between the different ability groups would suggest that $\dot{V}O_{2peak}$ may not be such a key performance indicator of young elite players.

The present results demonstrate that a comprehensive battery of physical performance tests can discriminate between different groups of elite young players classified on the basis of coach opinion. Moreover, it was observed that a greater number of those elite players who were classed by their coaches as being 'above average' for their academy age group in terms of their 'global soccer ability' went onto secure professional playing contracts. Added to this, the finding that the 'above average' players displayed superior physical performance in a number of measures, including, vertical jump (RJ; CMJ; CMJA), sprint speed (10 m and 20 m), agility and estimated $\dot{V}O_{2peak}$ would suggest that these physical attributes are key to the future success of an elite young player.

9.3.4.1 Practical applications

The findings presented in the current study provide further evidence to the practitioner of the need to monitor the physical attributes of their elite young players. Physical performance assessments of vertical jump (RJ; CMJ; CMJA), sprint speed (10 m and 20 m), agility and estimated $\dot{V}O_{2peak}$ will assist in the process of talent identification and to help to maximise the physical performance development of those players who are selected for the elite academy programme.

9.4 PROFESSIONAL AND NON-PROFESSIONAL ACADEMY GRADUATES: ANTHROPOMETRIC AND PHYSICAL PERFORMANCE CHARACTERISTICS

9.4.1 INTRODUCTION

The previous sections in Chapter 9 have shown that a number of anthropometric and physical performance variables, including standing height, vertical jump, speed, agility, and estimated $\dot{V}O_{2peak}$ are able to distinguish between elite and non-elte players (Chapter 9.1), released and retained academy players (Chapter 9.2) and coach assessed ability groups of elite young players (Chapter 9.3). The results of these three separate studies suggest that variable best able to distinguish between different groups of players is agility. However, it is the ultimate aim of the academy system to produce professional players and surprisingly very few studies have addressed this issue. One study of 64 English Football Association national schoolboys aged 14 to 16 years attempted to identify key factors that may distinguish between players who went on to sign professional contracts with those who did not (Franks et al., 2002). However, despite recording various anthropometric (standing height; body mass; body fat percentage), physical performance measurements (Multi-Stage Fitness Test; 15 m and 40 m sprint times) no significant differences were found to exist between those players who were deemed to be more successful by signing a professional contract and the less successful players who failed to sure a professional contract (Franks et al., 2002). Fitness profiles of successful players have nonetheless been indicated to be a valuable resource to assist in the process of talent selection (Williams and Reilly, 2000; Stolen et al., 2005). Although again based on a relatively small sample of 34 elite senior and junior players it has been suggested that in order to play soccer at the professional level the major fitness determinants are agility (15 m agility run test) and specific endurance (Yo-Yo Intermittent Recovery Test Level 1) (Mujika et al., 2009).

In addition to physical performance tests previous reports on young soccer players have highlighted differences in the anthropometric characteristics of different standards of players (Gil et al., 2007; le Gall et al., 2010). Gil and colleagues (2007) have indicated that body size was an important criterion in talent selection following their study of 241 youth soccer players. In another comparatively large study of 161 elite youth players it was found that players who went on to play professionally were differentiated from their amateur peers as being both taller and heavier (le Gall et al., 2010).

Therefore, a small number of studies have been published which have attempted to report on the anthropometric and physical performance characteristics which can be attributed to success in terms of becoming a professional soccer player. However, the majority of these studies have been based on relatively small sample sizes of players which limit the strength of the conclusions which can be drawn from these investigations. Thus, the aim of the present study was to establish the key anthropometric and physical performance characteristics of those who were successful in securing professional playing contracts upon their graduation from English soccer academies. The hypothesis to be tested was that academy players who went on to sign a professional contract would be best distinguished by agility.

9.4.2 METHODS

9.4.2.1 Participants

A total of 954 elite child and adolescent soccer players (age 16.3±1.6 years; height 174.3±8.7 cm; body mass 66.1±10.8 kg) participated in this study. All the subjects were registered at one of twelve professional soccer club academies in England.

Estimated peak oxygen uptake ($\dot{V}O_{2peak}$) was measured in 208 subjects (51 professional graduates and 157 non-professional graduates) using the MSFT (Ramsbottom et al., 1988). A detailed description of the MSFT protocol can be found in section 3.4.5.

9.4.2.2 Participant information

The professional playing status of the participants, all of whom were over 18 years of age at the end of the 2007/2008 playing season (11.05.08) was sourced from the International Soccer Bank (Neustadt, Germany). Players were assigned into one of two groups, those who went on to gain professional contracts (professional graduates) and those who failed to gain a professional contract (non-professional graduates).

9.4.2.3 Procedures

A detailed description of the procedures and physical performance testing protocol can be found in sections 3.3 and 3.4.

9.4.2.4 Statistical analysis

Data were analysed using SPSS (Version 16.0, Chicago, Illinois, USA) and MLwiN (Version 2.16, Bristol, U.K.). Descriptive statistics were calculated. Independent *t*-tests were used to investigate differences in anthropometric and physical performance variables between both professional status (professional graduates vs. non-professional graduates) and professional playing status (professional appearance vs. no professional appearance). One-way analysis of variance (ANOVA) was used to investigate differences in anthropometric and physical performance variables between different professional playing levels (Premiership; Championship; League 1; League 2). When a significant professional playing level effect was found a Tukey post hoc test was used to test differences among means.

An additive polynomial multilevel model (Goldstein et al., 1994) was used to examine the development of standing height and body mass in professional and non-professional graduates. Age and age squared (centred on age 15) were used as explanatory variables, and a dichotomous variable (player was given a professional contract or not) was added to investigate if any differences existed between professional graduates and non-professional graduates. All parameters were fixed, except the constant parameter, which was allowed to vary randomly at levels 1, 2 and 3 (repeated measurements, player and club respectively).

The extent to which there were differences in performance characteristics (RJ, CMJ, CMJA, 10 m speed, 20 m speed and agility) between professional and non-professional graduates was investigated using a multiplicative allometric model (Nevill et al., 1998). The development of a particular performance variable (which was log transformed for the analysis) was explained as a function of log transformed body mass, log transformed height, age and age squared. A dichotomous variable (player was given a professional contract or not) was added to the model to investigate if any differences existed between professional and non-professional graduates. All parameters were fixed except the constant parameter, which was allowed to vary randomly at levels 1, 2 and 3 (repeated measurements, player and club respectively) and the age and age squared variables which were allowed to vary at level 2 (player). Statistical significance was accepted at the 95% confidence level ($p<0.05$).

A multilevel binomial logistic regression (using the logit transformation) was used to compare professional with non-professional graduates. Age and the anthropometric variables standing height and body mass were added to the model first. Performance variables (RJ, CMJ, CMJA, 10 m speed, 20 m speed and agility) were then added sequentially. Variables were removed if the parameter estimate was less than 1.96 times its standard error. Where significance of a parameter was altered by the addition of another variable, the variable with the greater ratio of parameter estimate to its standard error was retained. Values are reported as mean (±SD).

9.4.3 RESULTS

9.4.3.1 Player group characteristics

A total of 197 (20.6%) of the 954 players studied were awarded a professional playing contract (Table 9.4.1). Of those professional graduates, 123 (12.9%) had gone on to make a professional playing appearance (Table 9.4.1). Professional graduates were older than the non-professional graduates at the time of testing (16.8±1.4 vs. 16.1±1.6) (Table 9.4.1). Professional graduates who had made a playing appearance were older than those who had yet to make a professional playing appearance at the time of testing (17.2±1.2 vs. 16.2±1.2) (Table 9.4.1). The majority (91) of the 123 professional graduates were at Premiership clubs, with only 18 players at League 2 clubs (Table 9.4.2). The professional graduates at Championship clubs were significantly older than those at League 2 and Premiership clubs (Table 9.4.2). Whilst the professional graduates who had made a professional appearance for Championship clubs were significantly older than those players who had made a professional appearance for a League 2 club (Table 9.4.2).

Table 9.4.1. Distribution of players in relation to professional status (mean±SD).

Professional Status	Professional graduates		Non-professional graduates	
	N	Chronological age at the time of testing (years)	n	Chronological age at the time of testing (years)
Professional contract	197	16.8±1.4	757	16.1±1.6*
Professional appearance	123	17.2±1.2		
No professional appearance	74	16.2±1.2**		

Significant differences between both professional status and professional appearance status based on independent *t*-test analysis.
*Significantly different from professional players $p<0.01$
**Significantly different from professional appearance $p<0.05$

Table 9.4.2. Distribution of professional graduates in relation to playing and appearance level (mean±SD).

Highest Professional Contract				Professional Appearance				
League	N	%	Chronological age at the time of testing (years)	Yes			No	
				n	%	Chronological age at the time of testing (years)	n	Chronological age at the time of testing (years)
Premiership	91	9.5	16.7±1.4[a]	55	5.8	17.1±1.3	36	15.9±1.3*
Championship	45	4.7	17.4±1.1	31	3.2	17.6±1.0	14	17.0±1.3
League 1	43	4.5	16.8±1.3	29	3.0	17.0±1.2	14	16.3±1.5
League 2	18	1.9	16.2±1.3[a]	8	0.8	16.2±1.3[a]	10	16.2±1.4

Significant differences between professional appearance status based on independent *t*-test analysis.
*Significantly different from professional appearance $p<0.01$
Significant differences between professional playing level based on one-way ANOVA and post hoc Tukey analysis.
[a]Significantly different from championship $p<0.05$

9.4.3.2 Anthropometric characteristics

Professional graduates were significantly taller (3.6 cm) and heavier (3.9 kg) than non-professional graduates (177.1±7.3 vs. 173.5±8.8 cm and 69.2±9.3 vs. 65.3±11.0 kg, respectively; $p<0.01$; Figure 9.4.1). The professional graduates at Premiership clubs were significantly lighter than those at Championship clubs, 68.1±9.3 vs. 73.0±7.8 kg; $p<0.05$; Figure 9.4.1). The professional graduates at Premiership clubs who had made a professional playing appearance were significantly taller (3.3 cm; $p<0.05$) and heavier (6 kg; $p<0.01$) than those who had not made a professional appearance (Table 9.4.3). The professional graduates at Championship clubs who had made a professional appearance were only slightly taller (0.7 cm) but significantly heavier (5.5 kg; $p<0.05$) than those who not made a professional appearance (Table 9.4.3). Multilevel additive polynomial analysis revealed that professional graduates were 1.4 cm taller ($p<0.05$) and 1.2 kg heavier (NS) than non-professional graduates (Table 9.4.4, Figure 9.4.2 and Table 9.4.5, Figure 9.4.3).

No significant differences in BMI, Reciprocal Ponderal Index or ectomorphy values were found to exist between professional and non-professional graduates (Figure 9.4.4). The professional graduates at both Premiership and Championship clubs who had made a professional playing appearance had significantly higher BMI values than those who had not made a professional appearance (Table 9.4.6). The professional graduates at Championship clubs who had made a professional playing appearance had significantly lower RPI and ectomorphy values than those players who had not made a professional appearance (Table 9.4.6).

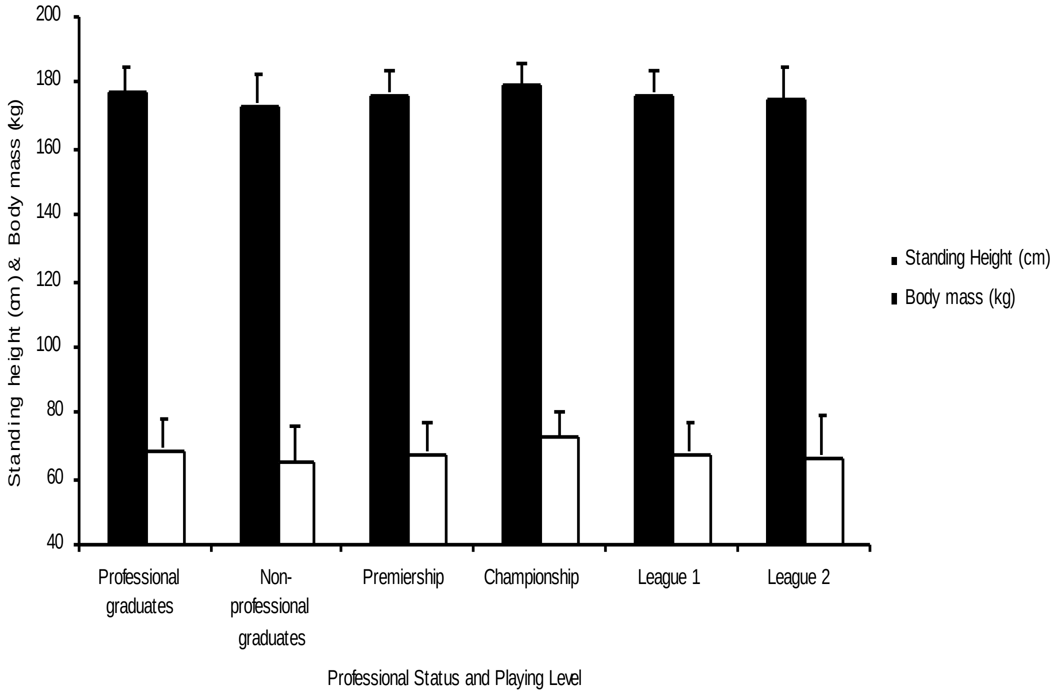


Figure 9.4.1. Anthropometric characteristics of professional vs. non-professional graduates, including professional graduates by playing level (mean±SD).

Significant differences between professional status based on independent *t*-test analysis.
[*]Significantly different from professional players p<0.01
Significant differences between professional playing level based on one-way ANOVA and post hoc Tukey analysis.
[a]Significantly different from championship p<0.05

Table 9.4.3. Body size characteristics of professional graduates by playing and appearance level (mean±SD).

League	Standing Height (cm)		Body mass (kg)	
	Professional Appearance		Professional Appearance	
	Yes	No	Yes	No
Premiership	178.0±7.2	174.7±7.0**	70.5±9.5	64.5±7.8*
Championship	179.7±6.1	179.0±6.8	74.7±7.3	69.2±7.9**
League 1	175.7±6.3	178.1±8.2	68.0±8.9	68.7±9.4
League 2	175.8±11.2	174.6±9.3	69.7±14.0	65.0±10.4

Significant differences between professional appearance status based on independent *t*-test analysis.
[*]Significantly different from professional appearance p<0.01
[**]Significantly different from professional appearance p<0.05

Table 9.4.4. Multilevel additive polynomial analysis of standing height (cm) in academy graduates, some of whom gained a professional contract.

Fixed Explanatory Variables	Parameter estimate (SE)
Constant	170.31 (0.400)**
Age (centred on age 15 years)	4.960 (0.061)**
Age squared (centred on age 15 years)	-0.798 (0.021)**
Professional contract	1.374 (0.565)**
Random Variance	
Level1 (Club)	1.336 (0.808)
Level 2 (Player)	44.820 (2.227)**
Level 3 (Repeated measurements)	2.504 (0.096)**
-2*loglikelihood (IGLS Deviance)	11705.998

**p<0.05

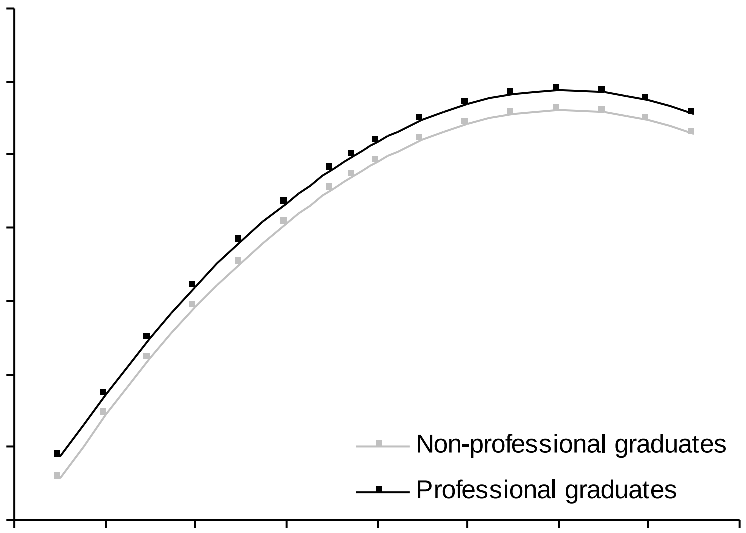


Figure 9.4.2. Standing height (cm) prediction in professional vs. non-professional graduates.
Standing height = 170.31 + 4.960*age (centred on 15 – see below) + -0.798 age2 ('age15' squared) + 0 if did not get a professional contract + 1.374 if did gain a professional contract. (Age centred on 15 means = players age-15. Therefore for calculations from the equation above age 15 = 0, 16 = +1 and 14 = -1 and so on. The players ages ranged from 12.5 to 19.75 for this data set.).

Table 9.4.5. Multilevel additive polynomial analysis of body mass (kg) in academy graduates, some of whom gained a professional contract.

Fixed Explanatory Variables	Parameter estimate (SE)
Constant	60.919 (0.456)**
Age (centred on age 15 years)	5.205 (0.073)**
Age squared (centred on age 15 years)	-0.561 (0.025)**
Professional contract	1.160 (0.653)
Random Variance	
Level1 (Club)	1.678 (1.039)
Level 2 (Player)	59.725 (2.972)**
Level 3 (Repeated measurements)	3.562 (0.136)**
-2*loglikelihood (IGLS Deviance)	12442.425

**p<0.05

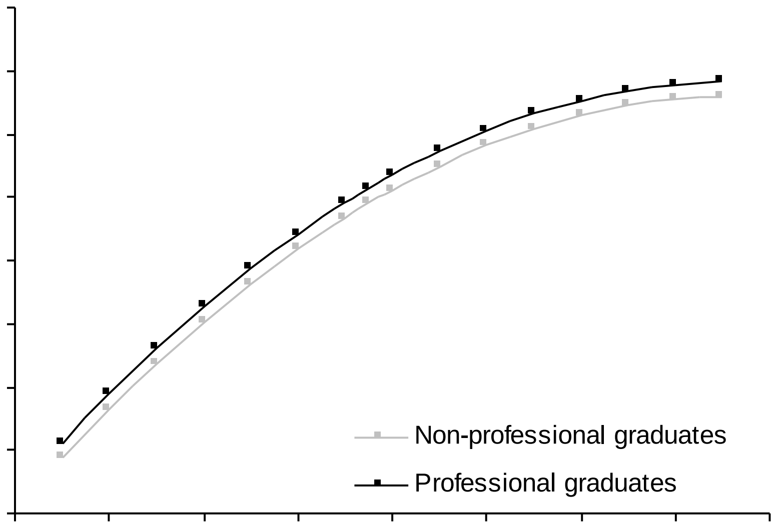


Figure 9.4.3. Body mass (kg) prediction in professional vs. non-professional graduates.
Body mass = 60.919 + 5.205*age (centred on 15 – see below) + -0.561 age2 ('age15' squared) + 0 if did not get a professional contract + 1.160 if did gain a professional contract. Age centred on 15 means = players age-15. Therefore for calculations from the equation above age 15 = 0, 16 = +1 and 14 = -1 and so on. The players ages ranged from 12.5 to 19.75 for this data set.).

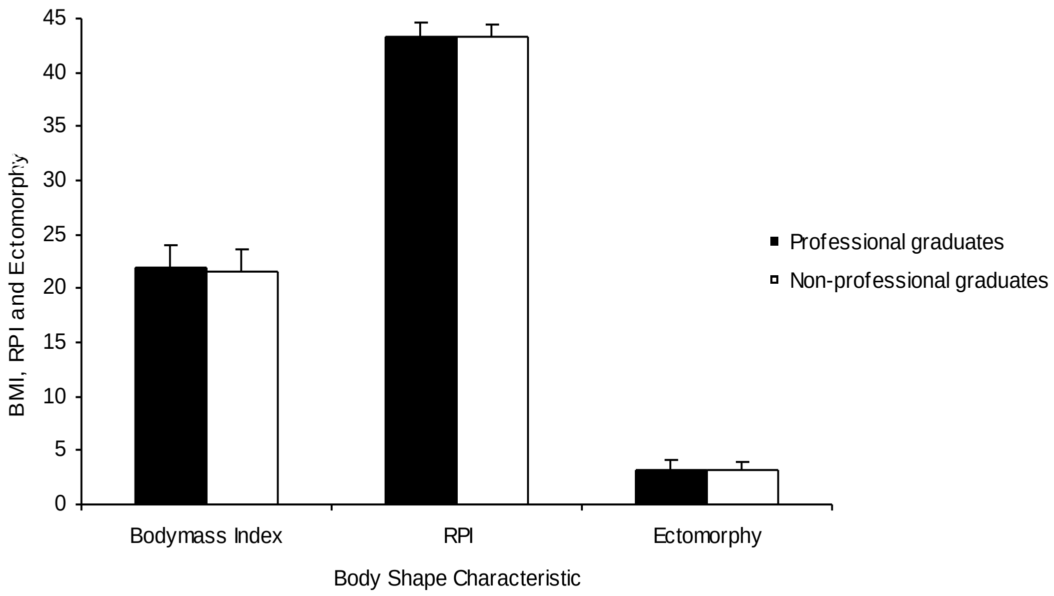


Figure 9.4.4. Body shape characteristics of professional vs. non-professional graduates (mean±SD).

Table 9.4.6. Body shape characteristics of professional graduates by playing and appearance level (mean±SD).

League	BMI		RPI		Ectomorphy	
	Professional Appearance		Professional Appearance		Professional Appearance	
	Yes	No	Yes	No	Yes	No
Premiership	22.2±2.1	21.1±1.9**	43.2±1.4	43.7±1.4	3.0±1.0	3.4±1.0
Championship	23.1±1.7	21.6±1.8*	42.7±1.2	43.7±1.2**	2.7±0.9	3.4±0.9**
League 1	21.9±2.0	21.5±1.7	43.2±1.2	43.6±1.1	3.0±0.8	3.3±0.8
League 2	22.3±1.9	21.2±2.1	42.9±0.8	43.6±1.3	2.8±0.6	3.3±0.9

Significant differences between professional appearance status based on independent *t*-test analysis.
*Significantly different from professional appearance $p<0.01$
**Significantly different from professional appearance $p<0.05$

9.4.3.3 Physical performance characteristics

Professional graduates had significantly higher vertical jump scores than non-professional graduates (RJ 38.8±5.4 vs. 36.6±5.4 cm, CMJ 39.4±5.6 vs. 37.5±5.5 cm and CMJA 45.6±6.5 vs. 42.8±6.4 cm, respectively; $p<0.01$; Figure 9.4.5). No significant differences in vertical jump height were found to exist between professional graduates at different playing levels. The professional graduates who had made a professional playing appearance in the Premiership, Championship and League 1 displayed significantly higher vertical jump scores than those players who had not made a professional playing appearance ($p<0.05$; Table 9.4.7). For example the RJ height of professional players at League 1 clubs who had made a professional appearance was 5.2 cm higher than those who had not made a professional playing appearance ($p<0.01$; Table 9.4.7). Multilevel additive polynomial analysis revealed that professional graduates had a 0.9 cm higher RJ ($p<0.05$; Table 9.4.8 and Figure 9.4.6), a 0.5 cm higher CMJ (NS; Table 9.4.9 and Figure 9.4.7) and a 1.0 cm higher CMJA ($p<0.05$; Table 9.4.10 and Figure 9.4.8) than non-professional graduates.

The professional graduates had significantly faster sprint and agility times than non-professional graduates (10 m sprint 1.72±0.1 vs. 1.75±0.1 s, 20 m sprint 2.99±0.1 vs. 3.07±0.2 s and agility test 4.09±0.3 vs. 4.26±0.3 s, respectively; $p<0.01$; Figure 9.4.9). The only significant differences in the sprint and agility performance of professional graduates at different playing levels was the slower 10 m and 20 m sprint times of League 2 players in comparison to Championship players (1.69±0.1 vs. 1.77±0.1 s and 2.95±0.1 vs. 3.06±0.1 s, respectively; $p<0.05$; Table 9.4.11). Premiership professional graduates who had made a professional playing appearance were significantly faster than those Premiership players who had not made a professional playing appearance in both the 10 m and 20 m sprint (1.70±0.1 vs. 1.74±0.1 s; $p<0.05$; 2.96±0.1 vs. 3.04±0.1 s; $p<0.01$; Table 9.4.11), the only exception being the 10 m sprint for those players at League 2 clubs (Table 9.4.11). Similarly, professional graduates at Championship clubs who had made a professional playing appearance were significantly faster than those who had not made a professional playing appearance on the agility test (4.04±0.3 vs. 4.23±0.3 s; $p<0.05$; Table 9.4.11). Multilevel additive polynomial analysis revealed that professional graduates were faster over 10 m by 0.05 s ($p<0.05$; Table 9.4.12 and Figure 9.4.10), faster over 20 m by 0.07 s ($p<0.05$; Table 9.4.13 and Figure 9.4.11) and faster over the agility test by 0.09 s ($p<0.05$; Table 9.4.14 and Figure 9.4.12) than non-professional graduates.

No significant differences in estimated $\dot{V}O_{2peak}$ values were found between professional and non-professional graduates (57.6±4.4 vs. 57.1±4.1 $ml.kg^{-1}.min^{-1}$, respectively; Figure 9.4.13). No significant differences in estimated $\dot{V}O_{2peak}$ values were found to exist between professional graduates at different playing levels. No significant differences in estimated $\dot{V}O_{2peak}$ values were found to exist between professional graduates who had made a professional playing appearance and those who had not (Table 9.4.15).

The multilevel binomial logistic regression analysis suggests that the two discriminating characteristics of the professional graduates were that they were taller than their non-professional peers and that they had better agility ($p<0.05$; Table 9.4.16). The model suggests that the odds of a player given a professional contract being taller than a player who does not receive a professional contract is 1.03 ($p<0.05$; Table 9.4.16). With respect to agility the odds are much greater: a player given a professional contract is 1.82 times more likely to have better agility than a player not given a contract ($p<0.05$; Table 9.4.16).

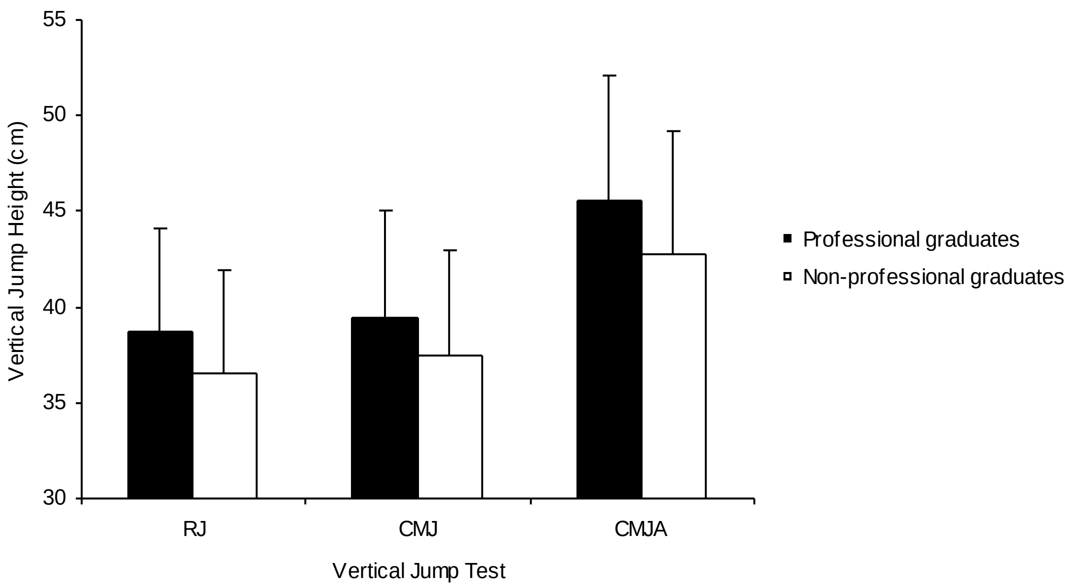


Figure 9.4.5. Vertical jump performance of professional vs. non-professional graduates (mean±SD).
Significant differences between professional status based on independent *t*-test analysis.
*Significantly different from professional players $p<0.01$

Table 9.4.7. Vertical jump performance of professional graduates by playing and appearance level (mean±SD).

League	RJ (cm)		CMJ (cm)		CMJA (cm)	
	Professional Appearance		Professional Appearance		Professional Appearance	
	Yes	No	Yes	No	Yes	No
Premiership	39.5±5.8	37.0±5.7**	39.9±5.7	37.8±5.7	46.4±8.0	43.1±5.8**
Championship	39.6±4.2	36.6±3.3**	40.6±4.9	37.9±3.8	47.3±4.9	44.5±3.7
League 1	41.5±5.3	36.3±5.4*	42.2±6.0	36.9±5.6**	48.2±6.2	44.1±5.3**
League 2	37.9±4.1	37.6±4.5	37.4±4.5	37.7±4.7	43.9±4.2	42.7±7.3

Significant differences between professional appearance status based on independent *t*-test analysis.
*Significantly different from professional appearance $p<0.01$
**Significantly different from professional appearance $p<0.05$

Table 9.4.8. Multilevel multiplicative allometric analysis of RJ height (cm) in academy graduates, some of whom gained a professional contract.

Fixed Explanatory Variables	Parameter estimate (SE)
Constant	3.539 (0.574)**
Body mass (kg) (Log transformed)	0.143 (0.041)**
Height (cm) (Log transformed)	-0.112 (0.134)
Age (centred on age 15 years)	0.038 (0.003)**
Age squared (centred on age 15 years)	-0.004 (0.001)**
Professional contract	0.024 (0.009)**
Random Variance	
Level1 (Club)	0.0035 (0.0013)**
Level 2 (Player)	0.0124 (0.0008)**
Level 3 (Repeated measurements)	0.0039 (0.0001)**
-2*loglikelihood (IGLS Deviance)	-4090.942

**p<0.05

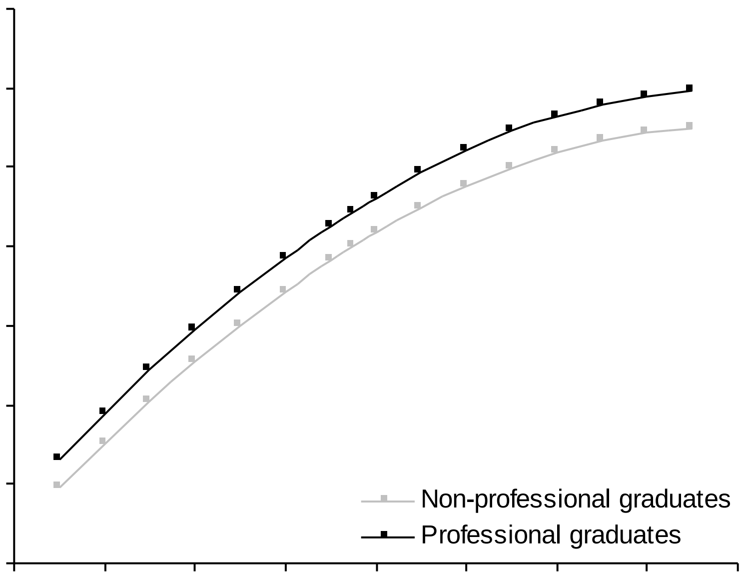


Figure 9.4.6. RJ height (cm) prediction in professional vs. non-professional graduates.

RJ height = Body mass(kg)$^{0.143}$ * standing height$^{-0.112}$ * exp(3.539 + 0.038*age + -0.004*agesquared)

NB. 0.024 gets added to the 'exp' term above if the player did gain a professional contract.

Table 9.4.9. Multilevel multiplicative allometric analysis of CMJ height (cm) in academy graduates, some of whom gained a professional contract.

Fixed Explanatory Variables	Parameter estimate (SE)
Constant	3.082 (0.564)**
Body mass (kg) (Log transformed)	0.174 (0.039)**
Height (cm) (Log transformed)	-0.042 (0.130)
Age (centred on age 15 years)	0.040 (0.004)**
Age squared (centred on age 15 years)	-0.006 (0.000)**
Professional contract	0.014 (0.009)
Random Variance	
Level1 (Club)	0.0023 (0.0009)**
Level 2 (Player)	0.0123 (0.0008)**
Level 3 (Repeated measurements)	0.0032 (0.0001)**
-2*loglikelihood (IGLS Deviance)	-4342.264

**p<0.05

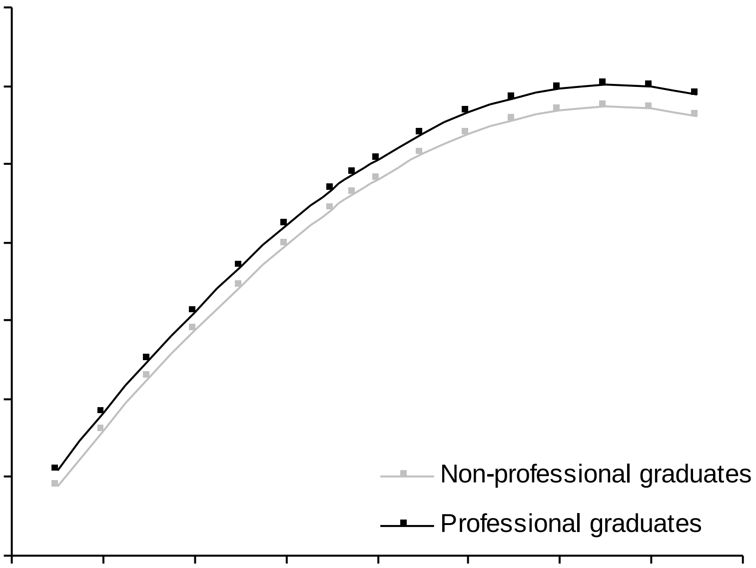


Figure 9.4.7. CMJ height (cm) prediction in professional vs. non-professional graduates.
CMJ height = Body mass(kg)$^{0.174}$ * standing height$^{-0.042}$ * exp(3.082 + 0.040*age + -0.006*agesquared)
NB. 0.014 gets added to the ‘exp’ term above if the player did gain a professional contract.

Table 9.4.10. Multilevel multiplicative allometric analysis of CMJA height (cm) in academy graduates, some of whom gained a professional contract.

Fixed Explanatory Variables	Parameter estimate (SE)
Constant	3.343 (0.552)**
Body mass (kg) (Log transformed)	0.176 (0.038)**
Height (cm) (Log transformed)	-0.069 (0.128)
Age (centred on age 15 years)	0.047 (0.004)**
Age squared (centred on age 15 years)	-0.006 (0.001)**
Professional contract	0.024 (0.009)**
Random Variance	
Level1 (Club)	0.0018 (0.0008)**
Level 2 (Player)	0.0115 (0.0008)**
Level 3 (Repeated measurements)	0.0029 (0.0001)**
-2*loglikelihood (IGLS Deviance)	-4446.161

**p<0.05

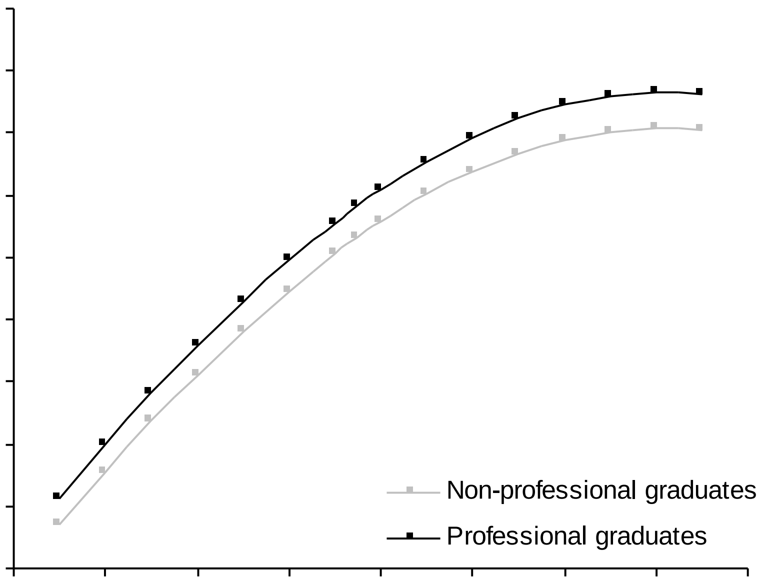


Figure 9.4.8. CMJA height (cm) prediction in professional vs. non-professional graduates.

CMJA height = Body mass(kg)$^{0.176}$ * standing height$^{-0.069}$ * exp(3.343 + 0.047*age + -0.006*agesquared)

NB. 0.024 gets added to the 'exp' term above if the player did gain a professional contract.

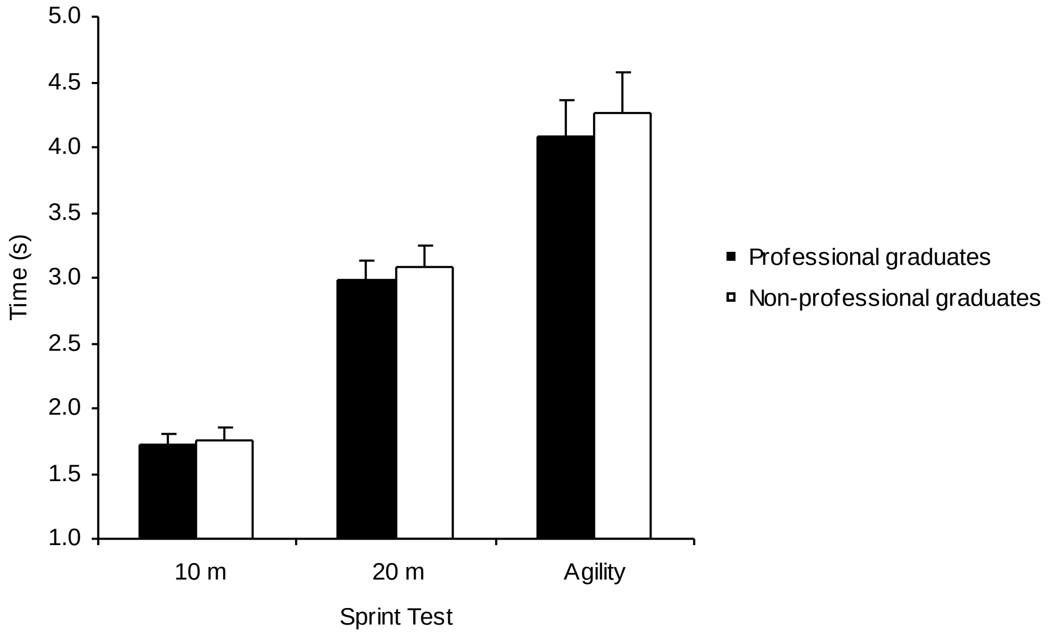


Figure 9.4.9. Sprint and agility performance of professional vs. non-professional graduates (mean±SD).
Significant differences between professional status based on independent *t*-test analysis.
*Significantly different from professional players p<0.01

Table 9.4.11. Sprint and agility performance of professional graduates by playing and appearance level (mean±SD).

League	10 m Sprint (s)		20 m Sprint (s)		Agility (s)	
	Professional Appearance		Professional Appearance		Professional Appearance	
	Yes	No	Yes	No	Yes	No
Premiership	1.70±0.1	1.74±0.1**	2.96±0.1	3.04±0.1*	4.05±0.3	4.11±0.3
Championship	1.69±0.1	1.70±0.1	2.93±0.1	3.00±0.1	4.04±0.3	4.23±0.3**
League 1	1.71±0.1	1.73±0.1	2.97±0.1	3.04±0.2	4.08±0.3	4.08±0.2
League 2	1.77±0.1	1.76±0.1	3.05±0.1	3.07±0.2	4.13±0.2	4.20±0.3

Significant differences between professional appearance status based on independent *t*-test analysis.
*Significantly different from professional appearance p<0.01
**Significantly different from professional appearance p<0.05

Table 9.4.12. Multilevel multiplicative allometric analysis of 10 m speed ($m.s^{-1}$) in academy graduates, some of whom gained a professional contract.

Fixed Explanatory Variables	Parameter estimate (SE)
Constant	1.623 (0.202)**
Body mass (kg) (Log transformed)	0.069 (0.015)**
Height (cm) (Log transformed)	-0.032 (0.048)
Age (centred on age 15 years)	0.017 (0.001)**
Age squared (centred on age 15 years)	-0.003 (0.000)**
Professional contract	0.008 (0.003)**
Random Variance	
Level1 (Club)	0.0005 (0.0001)**
Level 2 (Player)	0.0005 (0.0001)**
Level 3 (Repeated measurements)	0.0010 (0.0000)**
-2*loglikelihood (IGLS Deviance)	-8007.418

**p<0.05

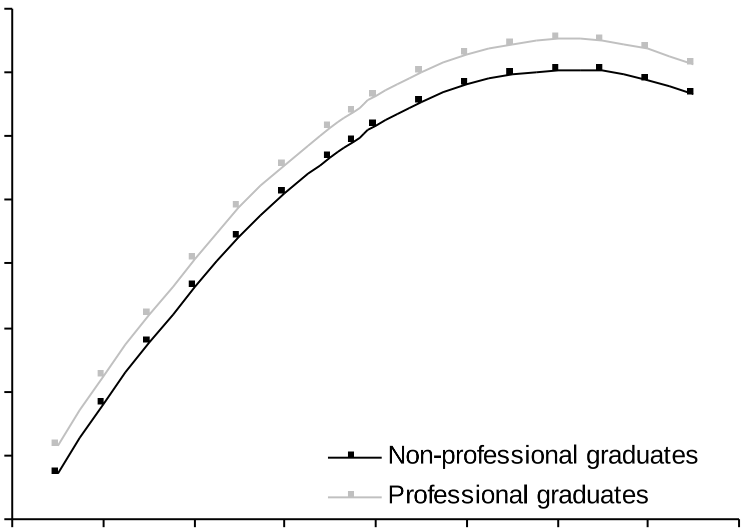


Figure 9.4.10. 10 m speed ($m.s^{-1}$) prediction in professional vs. non-professional graduates.
10 m speed = Body mass(kg)$^{0.069}$ * standing height$^{-0.032}$ * exp(1.623 + 0.017*age + -0.003*agesquared)
NB. 0.008 gets added to the ‘exp’ term above if the player did gain a professional contract.

Table 9.4.13. Multilevel multiplicative allometric analysis of 20 m speed (m.s^{-1}) in academy graduates, some of whom gained a professional contract.

Fixed Explanatory Variables	Parameter estimate (SE)
Constant	1.688 (0.195)**
Body mass (kg) (Log transformed)	0.073 (0.014)**
Height (cm) (Log transformed)	-0.024 (0.045)
Age (centred on age 15 years)	0.019 (0.001)**
Age squared (centred on age 15 years)	-0.003 (0.000)**
Professional contract	0.011 (0.003)**
Random Variance	
Level1 (Club)	0.0003 (0.0001)**
Level 2 (Player)	0.0012 (0.0002)**
Level 3 (Repeated measurements)	0.0007 (0.0000)**
-2*loglikelihood (IGLS Deviance)	-8452.088

**p<0.05

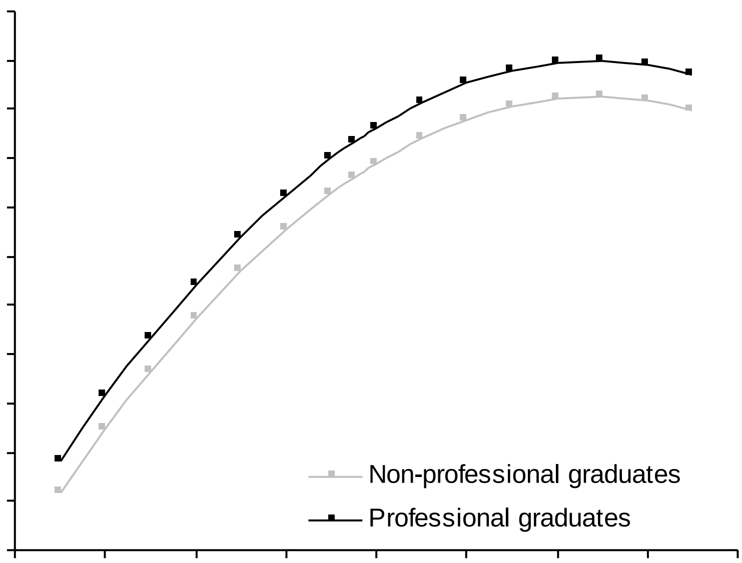


Figure 9.4.11. 20 m speed (m.s^{-1}) prediction in professional vs. non-professional graduates.

20 m speed = Body mass(kg)$^{0.073}$ * standing height$^{-0.024}$ * exp(1.688 + 0.019*age + -0.003*agesquared)

NB. 0.011 gets added to the 'exp' term above if the player did gain a professional contract.

Table 9.4.14. Multilevel multiplicative allometric analysis of speed during the agility test ($m.s^{-1}$) in academy graduates, some of whom gained a professional contract.

Fixed Explanatory Variables	Parameter estimate (SE)
Constant	1.037 (0.239)**
Body mass (kg) (Log transformed)	-0.038 (0.017)**
Height (cm) (Log transformed)	0.133 (0.056)**
Age (centred on age 15 years)	0.025 (0.002)**
Age squared (centred on age 15 years)	-0.003 (0.000)**
Professional contract	0.019 (0.003)**
Random Variance	
Level1 (Club)	0.0018 (0.0006)**
Level 2 (Player)	0.0019 (0.0001)**
Level 3 (Repeated measurements)	0.0011 (0.0000)**
-2*loglikelihood (IGLS Deviance)	-7340.267

**p<0.05

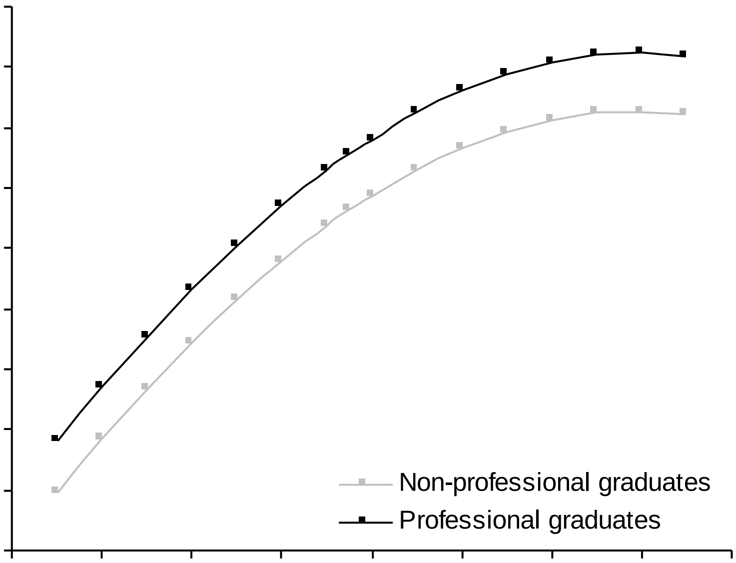


Figure 9.4.12. Agility test speed ($m.s^{-1}$) prediction in professional vs. non-professional graduates.
Agility = Body mass(kg)$^{-0.038}$ * standing height$^{0.133}$ * exp(1.037 + 0.025*age + -0.003*agesquared)
NB. 0.019 gets added to the 'exp' term above if the player did gain a professional contract.

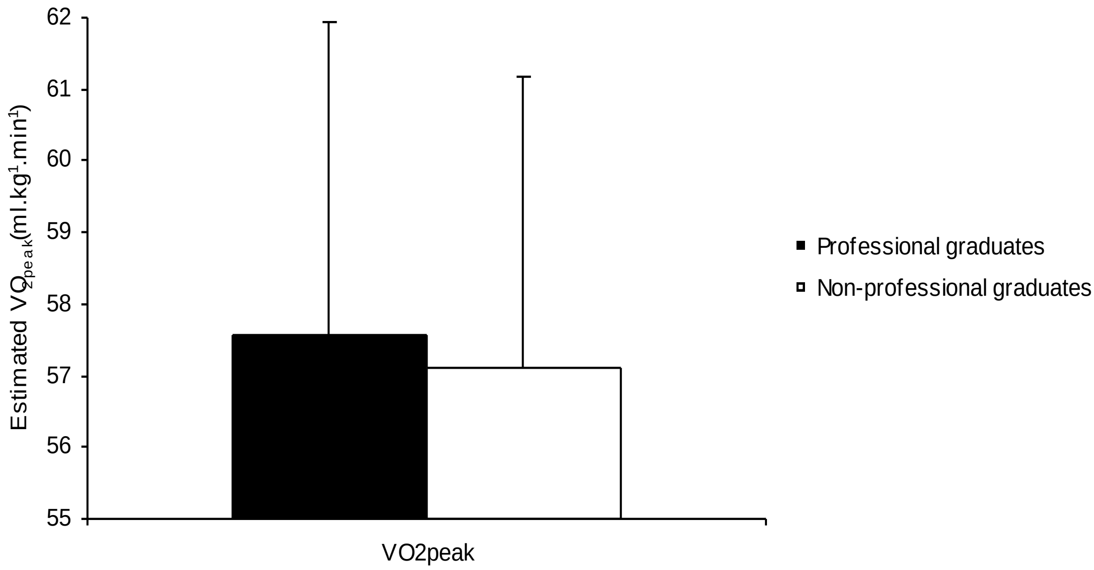


Figure 9.4.13. Estimated $\dot{V}O_{2peak}$ of professional vs. non-professional graduates (mean±SD).

Table 9.4.15. Estimated $\dot{V}O_{2peak}$ performance of professional graduates by playing and appearance level (mean±SD).

League	$\dot{V}O_{2peak}$ (ml.kg^{-1}.min^{-1})	
	Professional Appearance	
	Yes	No
Premiership	56.8±5.5	58.2±4.1
Championship	59.6±4.6	57.9±3.0
League 1	57.3±3.1	55.3±5.9
League 2	58.4±5.1	56.5±6.5

Table 9.4.16. Multilevel binomial logistic regression analysis of the discriminating anthropometric and physical performance characteristics of professional graduates in comparison to non-professional graduates.

Variable	*ß* (SE)	Odds ratio ($e^{ß}$)
Intercept	-1.299 (0.102)**	
Standing height (cm)	0.029 (0.009)**	1.03
Agility (m.s^{-1})	0.597 (0.218)**	1.82

**p<0.05

The best fit model was given by the following equation: Professional contract = -1.299 (0.102) + 0.029 (0.009) Heightcm + 0.597 (0.218) agility

9.4.4 DISCUSSION

The current study provides an indication of the highly selective environment of professional soccer in England. At the time of this study of 954 elite young players who had previously been selected to attend a professional football club academy only 197 had gone on to sign a professional contract (1 in every 5 players studied) whilst only 123 had made a professional playing appearance (1 in every 8 players studied) (Table 9.4.1).

The professional graduates demonstrated superior performance on several of the physical performance tests that were conducted, including vertical jump, speed and agility tests. Some anthropometric differences were also noted, with the professional graduates being taller and heavier than their non-professional counterparts.

The present findings are not in agreement with the observations of a similar study based on a smaller number (n=64) of elite academy soccer players by Franks and colleagues (2002). In the study by Franks and colleagues (2002) a comparison was made between players from the Football Association's National Centre of Excellence who succeeded in signing a contract as a full-time professional and those who failed to acquire a professional contract on graduation. The players could not be discriminated by anthropometric characteristics or sprint speed performance. The authors concluded that it may be difficult to distinguish between a group of highly selected players who have been exposed to systematic training, suggesting that other more complex factors may determine the players' suitability to be a professional. The lack of agreement between the current findings and those of Franks and colleagues (2002) may be partly explained by differences in number of players involved and the level of academies from which the elite young players were taken for the respective studies. Franks and colleagues (2002) only examined 64 players from a national academy which may reflect a more select group of players than the 2,252 elite young players from professional football club academies that were investigated in the present study.

The present results revealed the professional graduates to be significantly taller and heavier than the non-professional graduates (Figure 9.4.1). Furthermore, multilevel binomial logistic regression analysis suggests that professional graduates are 1.03 times more likely to be taller than non-professional graduates ($p<0.05$; Table 9.4.16). The observed differences in standing height and body mass cannot be solely explained by the finding that on average the professional players were approximately 6 months older than the non-professional players at the time of testing (Table 9.4.1). Nevill, Holder and Watts (2009) found that professional players have been getting taller (1.2 cm) and heavier (1.3 kg) per decade over the last four decades. The same authors also noted that goalkeepers, central defenders and central forwards were taller and heavier than players playing in wider positions. In the modern game the trend of players becoming taller and heavier along with the importance placed on body size in certain central playing positions by many coaches may provide some explanation for the current finding of taller and heavier players gaining professional contracts.

Some differences in the body size of players was observed between the different playing levels (Figure 9.4.1). Players at Championship clubs were the tallest and heaviest and were found to be significantly heavier than players at Premiership clubs (Figure 9.4.1). Again these findings may reflect the difference in age of players at Championship and Premiership clubs in the current study (Table 9.4.2). However, some of the difference may also be a reflection of ‘stronger’ more ‘physical’ players often associated with Championship clubs. This suggestion is given further support by the finding that those players at Championship clubs who had made a professional playing appearance were significantly heavier than those who had not (74.7±7.3 kg vs. 69.2±7.9 kg), despite the fact that no significant differences in chronological age was apparent between the two groups of players (Table 9.4.3). This latter finding may also reflect coaches concerns in relation to the ability of young professional players to cope with the physical demands of senior professional soccer. Consequently, the heavier young professional graduates who may possess more lean muscle mass are selected to play as opposed to their lighter peers who may be considered too ‘light body mass’ to deal with the exacting physical demands of professional soccer. Furthermore, the observed trend whereby heavier professional graduates are selected for games in preference their lighter counterparts would support the suggestion that body mass and stature are the best predictors of muscle strength (Katmarzyk, Malina and Beunen, 1997) and strong contributors to performance variation (Beunen et al., 1981).

Some significant differences in the body shape characteristics of the young professional graduates were observed, with those players who had made a professional appearance having higher BMI and lower Reciprocal Ponderal Index and ectomorphy values than players with no professional appearances (Table 9.4.6). These findings would suggest that players who have made a professional appearance are not as linear in body shape as players with no professional appearances. This may provide further support to the earlier suggestion that young professional players who are heavier as a consequence of greater lean muscle mass are more likely to be selected to play by coaches who perceive them as being ‘stronger’ and better able to handle the physical demands of the professional game. In a recent study on the changing shape of successful professional players it was suggested that body mass, whether in absolute terms or relative to standing height is a much less important determinant than standing height in the selection of successful professional players (Nevill, Holder and Watts, 2009). However, our results would appear to suggest that in younger professional players body mass, both in absolute terms and relative to standing height is an important determinant in the selection of players for professional appearances in the first team. It should be noted that the study by Nevill, Holder and Watts (2009) was based on older professional players (26.7±4.1 and 27.1±4.1 years). What is interesting to note is that the body shape characteristics (BMI; RPI and ectomorphy scores) of the young professional players who have made a professional appearance in the present study are similar to the values reported by Nevill, Holder and Watts (2009) for successful senior professional players. It would therefore appear that young professional graduates who display the body shape characteristics associated with older professional players are more likely to be selected to play for the first team.

In relation to physical performance the results of the present study revealed that vertical jump height (RJ; CMJ; CMJA) was significantly greater in professionl graduates compared to non-professional graduates ($p<0.01$; Figure 9.4.5). It is acknowledged that the difference in chronological age at the time of testing between the professional and non-professional graduates (16.8±1.4 vs. 16.1±1.6 years) may have had some influence on these results. However, this chronological age difference would not appear to fully account for the significant differences in vertical jump height observed between professional and non-professional graduates given the fact that in Chapter 6.1 no significant improvements in vertical jump performance between U16 and U17 players were found to exist (Table 6.1.2). Furthermore, multilevel additive polynomial analysis revealed that professional graduates had a 0.9 cm higher RJ ($p<0.05$; Table 9.4.8 and Figure 9.4.6), a 0.5 cm higher CMJ (NS; Table 9.4.9 and Figure 9.4.7) and a 1.0 cm higher CMJA ($p<0.05$; Table 9.4.10 and Figure 9.4.8) than non-professional graduates. Based on these observations of vertical jump performance it is reasonable to suggest that the professional graduates may possess greater levels of, lower limb maximum strength (Jaric et al., 1989), muscular power of the leg extensor muscles (Ashley and Weiss, 1994) and co-ordination of body segmental actions (Hudson, 1986) in comparison to non-professional graduates. These current findings are in agreement with studies which have compared senior professional and non-professional players and found that professional players score higher on vertical jump tests than non-professionals (Faina et al., 1988; Arnason et al., 2004). However, it should be noted that not all studies have found significant differences to exist between senior professional and non-professional players (Cometti et al, 2001; Franks et al., 2002). Indeed, the study of French senior professional and amateur players by Cometti and colleagues (2001) actually found higher CMJA scores in the amateur players (n=29) than in professional first (n=34) and second division players (n=32), (43.9±5.7 cm vs. 41.6±4.2 cm and 39.7±5.2 cm, respectively). The fact that the present study is based on a larger number (197 professional graduates; 757 non-professional graduates) of younger English players may explain the disparity in findings relating to vertical jump performance between the current study and the earlier study conducted by Cometti and colleagues (2001).

Further significant differences in vertical jump performance in the current study were also found to exist between professional graduates who had made a professional playing appearance and those who had not (Table 9.4.7). For example, despite no significant difference in the chronological age of professional graduates in League 1 who had or had not made a professional playing appearance, the vertical jump performance on all three jumps (RJ; CMJ; CMJA) was significantly greater in those players who had made a professional playing appearance (Table 9.4.7). This finding would appear to suggest that young professional graduates who display greater levels of leg strength and power, in addition to better co-ordination as indicated by superior vertical jump scores are more likely to be selected to play in the first team. The observations made in relation to vertical jump performance in the present study further support the contention that vertical jump height is a relevant performance index in soccer (Wisloff et al., 2004).

In accordance with the observations relating to vertical jump performance, professional academy graduates were found to be significantly quicker than non-professional academy graduates in terms of sprint speed (10 m and 20 m) and agility performance (Figure 9.4.9). Multilevel additive polynomial analysis also revealed that professional graduates were faster over 10 m by 0.05 s ($p<0.05$; Table 9.4.12 and Figure 9.4.10), faster over 20 m by 0.07 s ($p<0.05$; Table 9.4.13 and Figure 9.4.11) and faster over the agility test by 0.09 s ($p<0.05$; Table 9.4.14 and Figure 9.4.12) than non-professional graduates. Cometti and colleagues (2001) reported senior professional players to be faster than their amateur counterparts over shorter distances (10 m) which they suggested was more relevant to the activities which take place during a competitive game. Similarly an earlier study by Kollath and Quade (1993) found senior German professional players to be significantly faster over 5 m, 10 m, 20 m and 30 m in comparison to amateur players. Findings of this nature highlight why speed has been described as such an important component in soccer, with the ability to accelerate often deciding important outcomes of the game (Svensson and Drust, 2005). Further analysis of the present findings showed that professional academy graduates were 0.47 m ahead of the non-professional academy graduates after a 20 m sprint, which quite simply would mean they could reach the ball first. It was interesting to note that the greatest differences between the professional academy graduates and non-professional academy graduates occurred on the agility test. For example, the professional academy graduates were found to be 0.83 m ahead of the non-professional academy graduates over the 20.8 m course of the agility test. Furthermore, multilevel binomial logistic regression analysis suggests that the main discriminating physical performance characteristic of the professional graduates was that they were more agile, with a professional graduate being 1.82 times more likely to be quicker on the agility test than a non-professional graduate ($p<0.05$; Table 9.4.16). This finding supports the suggestion that elite players should possess the ability to change direction quickly (Reilly Bangsbo and Franks, 2000). Similar to the present findings Reilly, Bangsbo and Franks (2000) found that agility performance was the most powerful discriminator between elite and sub-elite 15-16 year old players. Also an earlier study by Raven and colleagues (1976) reported that an agility test distinguished senior professional soccer players from the normal population better than other field tests of strength, power and flexibility. The current study also found that professional academy graduates who had made a professional playing appearance in the Premiership were significantly faster over 10 m and 20 m than there counterparts who had not made a professional playing appearance (Table 9.4.11). Although only slightly faster over a 10 m and 20 m sprint, professional academy graduates in the Championship who had made a professional playing appearance were found to be significantly faster in terms of agility performance when compared to those players who had not made a professional playing appearance (Table 9.4.11). This finding adds further support to earlier suggestions that agility is the key attribute which discriminates elite players from others (Raven et al., 1976; Reilly, Bangsbo and Franks, 2000).

In the present study no significant difference was found in the estimated $\dot{V}O_{2peak}$ values of professional and non-professional academy graduates (Figure 9.4.13). This finding would appear to support the argument that speed, power and agility measures of performance differentiate between standards of player better than $\dot{V}O_{2peak.}$ Furthermore, there was a trend in the present study for academy graduates at Premiership clubs who had made a professional appearance to have lower estimated $\dot{V}O_{2peak}$ values than those who had not made a professional appearance (Table 9.4.15). However, other authors have pointed to the fact that approximately 98% of the total energy expenditure in a game is derived from aerobic metabolism, suggesting that endurance performance in soccer determined by $\dot{V}O_{2peak}$ to be a very important attribute (Bangsbo, 1994d; Helgerud et al., 2001). In the present study professional academy graduates were found to have an estimated $\dot{V}O_{2peak}$ of 57.6 $ml.kg^{-1}.min^{-1}$. However, it has previously been suggested that consistent reports of $\dot{V}O_{2max}$ values above 60 $ml.kg^{-1}.min^{-1}$ in elite players may imply a threshold below which an individual player is unlikely to possess the physiological attributes for success in elite level soccer (Reilly, Bangsbo and Franks, 2000). Furthermore, it has recently been proposed that given the game related performance advantages of a high level of $\dot{V}O_{2max}$ in soccer that it may be reasonable to expect $\dot{V}O_{2max}$ values of approximately 70 $ml.kg^{-1}.min^{-1}$ for a 75 kg professional player (Stolen et al., 2005). The fact that the estimated $\dot{V}O_{2peak}$ values of the professional academy graduates in the current study are considerably below this value put forward by Stolen and colleagues (2005) and the fact that no significant differences were found to exist between the professional and non-professional academy graduates would suggest that $\dot{V}O_{2peak}$ may not be such a key performance indicator of elite professional players. However, when comparing the current results with those of other studies the different methods employed to determine $\dot{V}O_{2peak}$ in the respective studies must be taken into consideration. For example, the MSFT which was used to estimate $\dot{V}O_{2peak}$ in the present study has a tendency to underestimate values of $\dot{V}O_{2peak}$ (Sproule et al., 1993).

In summary, in the present study significant differences in anthropometric and physical performance characteristics were found to exist between professional and non-professional graduates from elite English soccer academies. In comparison to the non-professionals the professional graduates were taller and heavier, had higher vertical jumps and were faster in terms of sprint speed and agility performance. Furthermore, there was a trend for professional graduates who had made a professional appearance to be taller and heavier with superior physical performance characteristics in comparison to professional graduates who had not made a playing appearance. These findings suggest that an elite young players graduation from the academy environment into professional soccer can be determined to some extent by their anthropometric and physical performance characteristics. Multilevel analysis suggests that the key discriminating characteristics of academy players who went on to gain professional contracts were that they were taller than their peers and had better agility.

9.1.4.1 Practical applications

This study has established that standing height and agility are the key anthropometric and physical performance characteristics of those elite young players who are successful in securing professional playing contracts upon their graduation from English soccer academies. This information should aid the practitioner by providing a focus for talent identification and subsequent physical development programmes. The use of multilevel modelling in the study also presents practitioners with an outline of the development of anthropometric and physical performance characteristics in professional and non-professional graduates.

CHAPTER 10
GENERAL DISCUSSION

10.1 INTRODUCTION

The objective of this chapter is to assimilate the findings of the respective studies which constitute this thesis on the physical development, and progression to professional soccer, of elite child and adolescent players. To facilitate this process the hypotheses that were tested are either accepted or rejected based upon the results of the studies which were undertaken.

10.2 HYPOTHESIS TESTED

1. 'Coaches, fitness professionals and players perceive the physical aspects of performance in soccer to be very important in the context of the elite player'. Accepted.

The majority of coaches and players perceived technical and physical/physiological attributes as being most important in relation to the elite player. However, most fitness professionals actually suggested physical/physiological as opposed to technical attributes as being most important. Coaches recognised speed as being the most important attribute while both fitness professionals and players attached more importance to endurance.

The physical attributes of a player were regarded as having a crucial role to play in the process of offering professional contracts to players. Coaches as opposed to fitness professionals and players placed the most importance on a player's physical attributes when considering the process of offering a professional playing contract.

Most coaches, fitness professionals and players displayed the opinion that the physical/physiological attributes of players are more important in terms of the modern day game. It was also suggested that modern players had advanced in terms of a number of physical characteristics over the last 30 years, with speed being viewed as one of the main physical characteristics to have improved in relation to the modern player.

2. 'Physical based field tests provide a valid and reliable tool for the assessment of physical/physiological performance characteristics in elite young players'. Accepted.

Logical validity of the physical performance test battery employed in the current study was demonstrated by the fact that the tests used examined the aspects of physical performance that were identified by coaches, fitness professionals and players as being the most important physical aspects of soccer performance. It was deemed important to test a number of different physical attributes, although a particular emphasis on the importance of testing both speed and endurance was noted.

Some coaches, fitness professionals and players thought it possible to make accurate assessments of players physical attributes from observing a game. However the majority considered that objective measurements taken from physical performance tests offered a more accurate assessment of physical performance than subjective observations of a game.

The majority of coaches, fitness professionals and players believed that both laboratory and field based tests were valuable tools of physical performance assessment in the soccer environment. Although, it was evident that field based tests were considered to be of more value than laboratory based assessments.

Construct validity of physical performance testing was demonstrated by the vertical jump (RJ; CMJ; CMJA), speed (10m and 20m) and agility tests being able to distinguish between both different age and ability groups of players. For example, the highest level of physical performance on these tests was observed in the oldest players (U15s-U18s), with the lowest level of physical performance being associated with the youngest players (U9s-U11s). Heart rate response to the MSFT also distinguished between different age groups of players, with heart rate for a given running speed decreasing with increasing age. However, the recovery heart rate values did not distinguish between different age groups of players, and therefore could not be considered a valid measurement tool.

The absolute and relative reliability of all the physical performance tests was established, the only exception being the recovery heart rate values which displayed insufficient reliability for a physical field test. Further analysis also revealed higher levels of relative reliability to be evident in the older (U15s-U18s) as opposed to the younger (U9s-U11s) age groups.

On the basis of the multitude of methods of validity and reliability assessment employed in this thesis, with the exception of the heart rate recovery values, all the physical field based performance tests analysed demonstrated logical and construct validity, and were shown to be reliable and objective tools to assess the physical characteristics of young elite soccer players.

3. 'The physical performance of elite young players in professional English soccer academies improves with chronological age from the under 9 to under 19 years age group squads.' Rejected.

Significant year-on-year improvements in all physical performance measures were evident in the younger age groups. However, no significant year-on-year improvements were evident above the U15 age group for the CMJ, CMJA and 10m sprint tests, above the U16 age group for the RJ and 20m sprint tests and above the U17 age group for the agility test and estimated $\dot{V}O_{2peak}$.

Based these findings of what is to date the largest cross sectional analysis of physical performance in elite young players it would appear that improvements in physical performance are confined to the younger age groups only.

4. 'The anthropometric and physical performance characteristics of elite young players varies in relation to playing position'. Accepted.

The majority of coaches, fitness professionals and players considered that the relative importance of the various physical components differed in relation to playing positions. For example, agility and balance/co-ordination were considered to be the most important physical attributes for a goalkeeper, with little importance being placed on endurance and speed endurance.

Analysis of elite young players anthropometric characteristics in relation to playing positions revealed goalkeepers and centrebacks to be taller and heavier in comparison to other positions, in particular, fullbacks and midfielders in the U11 to U19 age groups.

Positional differences in the physical performance characteristics of the elite young players were also established. Forward players were found to display superior vertical jump and sprint (10 m and 20 m) performances in comparison to other playing positions in some age groups. It was also evident in general that the sprint and agility performances of goalkeepers were inferior to those of the outfield players. The estimated $\dot{V}O_{2peak}$ values of goalkeepers were also found to be lower in comparison to some outfield players in a number of age groups.

Initial interpretation of coaches, fitness professionals and players perceptions of physical performance in soccer revealed the opinion that different physical attributes were associated with different playing positions. The subsequent analysis of anthropometric and physical performance characteristics of elite young players supports this contention, with anthropometric and physical performance differences being evident between playing positions.

5. 'Elite young Black players will perform better than elite young White players on soccer specific physical performance tests.' Partially Accepted.
The questionnaire analysis exposed a widely held belief amongst coaches, fitness professionals and players that players from certain ethnic backgrounds were naturally more physically able in comparison to other players. In particular this belief was found to be associated with Black African and Black

Caribbean players. This perception of being more physically able was particularly related to the attributes of speed, power and strength.

Evidence of significant differences in the anthropometric characteristics of elite young Black players and White players was found in the present thesis. There was a trend for Black African and Black Caribbean players to be taller than White players especially in the younger age groups, whilst in the majority of the age groups both body mass and BMI values were lowest in the White players.

Analysis of the physical performance characteristics of Black players and White players also revealed a number of significant differences to exist. The main differences in physical performance between the Black and White players were observed in relation to vertical jump performance (RJ; CMJ; CMJA). Black African and Black Caribbean players were found to jump significantly higher than the White players in the majority of the age groups studied. Fewer significant differences were noted in the sprint (10m and 20m) and agility performance of the Black and White players. However, although no significant differences were found it was evident that the estimated $\dot{V}O_{2peak}$ values of the White players were higher than those of the Black African and Black Caribbean players in the most of the age groups studied.

The questionnaire relating to physical performance in soccer at the outset of the thesis exposed a perception among coaches, fitness professionals and players that Black players displayed better physical performance attributes. Subsequent analysis of the respective anthropometric and physical performance characteristics of elite young Black players and White players would appear to partially support this belief.

6. 'The selection process in elite youth soccer currently favours the older and more mature players.' Accepted.

The investigation of the season of birth distribution in elite young players demonstrated evidence of a relative age effect, with 46.5% and 9% of players having birthdates between September - November (1st Quarter) and June – August (4th Quarter) of the selection year. This relative age effect was found to be evident in all academy age groups studied from U9 to U19 years.

Further analysis revealed a number of differences to be evident in the anthropometric and physical performance characteristics of players born in different quarters of the selection year. Those players born in the early part of the selection year were in general taller and heavier and had a propensity to jump higher (RJ, CMJA), sprint faster (20m) and be more agile.

The combined evidence provided in this thesis relating to the existence of a relative age effect in elite young Academy players and the positive impact that being born in the early part of the selection has on physical performance would appear to support the belief that the selection process in elite youth soccer currently favours the older more mature players.

7. 'Players advanced in biological maturity demonstrate a better level of physical performance'. Accepted.

An investigation was undertaken on sexual maturity and its effect on the anthropometric and physical performance characteristics of elite young players. This study found that the stage of sexual maturity was significantly positively correlated with improved physical performance on all the tests that were undertaken.

It would appear that the positive influence that advanced maturity status has on physical performance characteristics of the players is mainly a product of the associated increase in standing height and body mass.

8. 'The greatest changes in physical performance occurs at the time corresponding with the peak height or weight velocity'. Part accepted.

A longitudinal study was carried out over three seasons (2002-2003; 2003-2004; 2004-2005) which was the first of its kind to use multilevel modelling analysis to provide an understanding of developmental changes in physical performance in elite child and adolescent soccer players. The results of this longitudinal study suggest that the peak rate of change in sprint speed in adolescent soccer players coincides with peak height velocity, but the peak rate of change in vertical jump occurs later and closer to their peak in weight velocity. However, the pattern in the rate of change in agility was different from that seen in all other variables and the peak change occurred in the youngest players well in advance of PHV.

9. 'Soccer ability group (non-players vs. school players; school pupils vs. academy players; club academy players vs. international academy players) could be distinguished on the basis of anthropometric and/or physical performance characteristics.' Part accepted.

The questionnaire analysis associated with physical performance in soccer revealed the perception that a players physical attributes improved in relation to playing standard. In relation to this perception the majority of coaches, fitness professionals and players considered the physical attributes of international players to be superior to those of club players. In particular it was suggested that international players were faster, more agile and possessed better balance/co-ordination.

One area of investigation in the thesis focused on the anthropometric and physical performance characteristics of young boys throughout the full spectrum of abilities from non-players and non-elite players to elite club and international players. The analysis suggested that there was a progressive improvement in the physical performance of young boys as the playing standard increased from non-players and non-elite players up to elite club academy players. For example, in comparison to the non-elite school pupils the elite academy players displayed higher vertical jump (RJ; CMJ; CMJA) and estimated $\dot{V}O_{2peak}$ values and were faster in terms of both sprint speed (10 m and 20 m) and agility. However, few such differences were evident at the elite level between club academy players and international academy players, where only RJ performance was found to be better in the international academy players.

These findings suggest that physical performance of players does improve as the standard of player steps up from non-player to non-elite player (non-player vs. school team player) and from non-elite to elite player (school pupil vs. club academy player), supporting the perception that a players physical attributes improved in relation to playing standard. However, the finding that club academy and international academy players displayed similar levels of physical performance suggests that at the highest playing standards (club academy player vs. international academy player) physical performance does not improve as it was perceived to by coaches, fitness professionals and players.

10. 'Retained academy players would have better physical performance characteristics than released academy players and that agility might distinguish best between retained and released players'. Accepted.
An evaluation of released and retained academy players found that retained players displayed significantly better physical performances in terms of vertical jump, sprint speed, agility and estimated $\dot{V}O_{2peak}$. However, the biggest difference in physical performance was observed on the agility test, with retained players 1.95 times more likely to be faster than released players.

11. 'Anthropometric and/or physical performance characteristics could distinguish between elite young players placed in different ability groups on the basis of coach opinion'. Accepted.
A comparison of different ability groups of players based on coaches assessments of 'global soccer ability' showed that those players considered to be 'above average' for their academy age group exhibited a significantly higher standard of physical performance on vertical jump, speed and agility tests than 'average' and 'below average' players, respectively. It was also noted that the main difference in the physical performance between the 'average' and 'below average' players was on the agility test, with 'average' players 2.28 times more likely to be faster than 'below average' players'.

12. 'Academy players who went on to sign a professional contract would be best distinguished by agility.' Accepted.

In comparison to non-professional academy graduates those players who went onto gain professional playing contracts demonstrated superior performance on several of the physical performance tests that were conducted, including vertical jump, speed and agility tests. However, the key discriminating physical performance characteristic of academy players who went on to gain professional contracts was that they had better agility.

10.3 DISCUSSION

The research process adopted within this thesis follows a logical pathway in the investigation of the physical development, and progression to professional soccer, of elite child and adolescent academy players. Firstly, an assessment of current opinion with regard to physical performance in soccer was made. This investigation involved the administration of a detailed questionnaire to coaches, fitness professionals and players. Secondly, a valid and reliable battery of physical field tests was established with which the physical performance characteristics of elite child and adolescent soccer players could be investigated. Finally, this battery of physical performance tests was administered to elite child and adolescent players in English professional soccer academies over a three year period. The discussion that follows provides a synopsis of the findings relating to the physical development and performance characteristics of elite child and adolescent soccer players.

The questionnaire analysis (Chapter 4) established the importance with which those involved in soccer placed on players physical performance characteristics in relation to elite soccer performance. The valid and reliable battery of field based physical performance tests (Chapter 5) that were used throughout the thesis were able to distinguish between different ability groups of players, including, non-elite vs. elite young players (Chapter 9.1), released vs. retained academy players (Chapter 9.2), 'average' vs. 'above average' academy players (Chapter 9.3) and non-professional vs. professional academy graduates (Chapter 9.4). As a result of these investigations the significance of certain physical performance characteristics were highlighted in relation to playing at the elite level. For example, in comparison to the non-professional academy graduates the professional academy graduates were taller and heavier, had higher vertical jumps and were faster in terms of sprint speed and agility performance (Chapter 9.4). Furthermore, multilevel modelling suggests that the two discriminating characteristics of academy players who went on to gain professional contracts were that they were taller than their peers and that they had better agility (Chapter 9.4). These findings enable a better understanding of the physical performance characteristics that are key to the future success of an elite young player.

It was interesting to note that coaches considered speed to be the most important physical attribute of an elite player (Chapter 4). The analysis of non-elite and elite players (Chapter 9.1) provided some support for this suggestion as elite players were found to be significantly quicker over 10 m and 20 m in comparison to non-elite players. The elite players were found to be 6.42 times more likely to be quicker over a 10 m sprint than non-elite players. For example, the U12 academy players were 0.19 s and 0.36 s faster or 0.87 m and 1.87 m ahead over a 10 m and 20 m sprint, respectively, in comparison to the school pupils. Clearly such significant differences in speed are of considerable importance when put into the context of a match where the ability of players to perform short sprints is often crucial for the match outcome (Wragg et al., 2000). Indeed it has been suggested that players must have the ability to accelerate quickly over short distances in order to meet the technical, tactical and physical demands of the game (Svensson and Drust, 2005). In light of the current findings and the observations of earlier studies (Brewer and Davis, 1992; Kollath and Quade, 1993; Cometti et al., 2001) the accurate assessment of speed would appear paramount with regard to the processes of talent identification and development of elite players.

Any form of assessment that is to be used to assist with such an important process as talent identification must be both valid and reliable. The validity and reliability of the battery of physical performance tests adopted in this thesis were established (Chapter 5). The questionnaire responses (Chapter

4) also emphasised the importance of assessing a number of different physical attributes, including power, endurance, speed and agility. In addition to assisting with the process of talent identification it was suggested that the objective information provided by physical performance testing can be used with players to identify strengths and weaknesses, monitor progress and development, provide a source of motivation and identify suitability for different playing positions (Chapter 4). Based on the present findings and those of other authors (MacDougall and Wenger, 1991; Balsom, 1994; Svensson and Drust, 2005) it is apparent that the use of physical performance testing in elite soccer provides important information which can be utilised to add an element of objectivity to a number of key decision making processes that are undertaken by coaches and trainers within the game in relation to players.

The investigation of current opinions within the game revealed a preference towards field based tests as opposed to laboratory based tests (Chapter 4). Clearly some of the problems that have previously been highlighted with regards to laboratory based testing by Svensson and Drust (2005) including access to facilities, expense and their time consuming nature would have been unmanageable in a study of this size and nature where a total of 2,252 elite academy players and 520 school pupils were assessed on a battery of physical performance tests over the course of three years. The experiences and findings (Chapter 5) which have been taken from the current investigation would appear to support previous suggestions that physical performance tests conducted in the field enhance the specificity and therefore the validity of the evaluations (Balsom, 1994) which ultimately may provide a better indication of the ability to perform during a game than laboratory based evaluations (Svensson and Drust, 2005).

From the perspective of the applied practitioner one of the main aims of this thesis was to provide normative values for elite young players on relevant anthropometric measurements and physical performance tests from the U9 to U19 age groups (Chapter 6.1). Based on the assessment of 2,252 elite young players this is the largest and most comprehensive study of its kind to date, providing normative data and performance standards for elite young players at English professional clubs (Chapter 6.1). The cross-sectional study reported in Chapter 6.1 was further complemented by the longitudinal analysis presented in Chapter 8.0. For the first time to date, multilevel modelling was used to examine longitudinally the effects of age, standing height and body mass on physical performance characteristics of elite young and adolescent soccer players (Chapter 8.0). Such information maybe used by coaches and sports scientists as a tool to support the process of talent identification in soccer. One of the major findings from the cross-sectional study was that the greatest changes in anthropometric and physical performance characteristics in the young elite players' occurred between the early to mid-teenage years (Chapter 6.1). Furthermore, the longitudinal results suggested that the peak rate of change in sprint speed in adolescent soccer players coincides with peak height velocity, but the peak rate of change in vertical jump occurs later and closer to their peak in weight velocity (Chapter 8.0). It was also observed that the pattern in the rate of change in agility was different from that seen in all other variables with the peak change occurring in the youngest players (Chapter 8.0). Clearly those working with young elite players need to be aware of the timing and magnitude of these changes and there effect on the processes of training and development, selection and talent identification.

Distinct physical attributes were perceived to be associated with different playing positions, for example, coaches considered speed to be the key attribute for forward players (Chapter 4). The present study demonstrated that both anthropometric and physical performance differences existed among specific playing positions in elite young soccer players (Chapter 6.2). A tendency for forwards to be the quickest outfield players over 10 m and 20 m was revealed, whilst goalkeepers and centrebacks were found to be taller and heavier than other players (Chapter 6.2). Observations of this nature provide a detailed understanding of the anthropometric and physical performance characteristics of elite young players in respect to specific playing positions in the modern game (Chapter 6.2).

In the first study of its kind thus far the subject of ethnicity was investigated in relation to physical performance in elite young soccer players (Chapter 6.3). A perception of Black African and Black Caribbean players being quicker, stronger and more powerful was revealed amongst coaches, fitness professionals and players (Chapter 4). One of the key findings from this area of the study was for Black players to display better vertical jump performance in comparison to White players in the majority of age groups, with faster sprint speed of Black players also being evident in some of the age groups studied (Chapter 6.3). It was suggested that the results relating to the physical performance of the Black players may offer some explanation for the finding whereby Black players were overrepresented in the forward playing position but underrepresented in the playing position of goalkeeper (Chapter 6.3). Primarily this section of the thesis provides an initial understanding of the interaction between ethnicity and physical performance in elite young soccer players. Given the beliefs that were found to exist in relation to ethnicity and physical performance in soccer this area of investigation is much warranted.

The current investigation demonstrated for the first time the existence of a relative age effect in all age groups from U9s to U19s in English professional soccer academies (Chapter 7.1). On the basis of this finding it was suggested that the relatively early age which English Academy players start (U9s) may compound the relative age effect because of the physical advantage (standing height and body mass) that those born early in the selection year in the younger age groups were found to have over players who were born later in the selection year (Chapter 7.1). It is paramount that coaches and those involved in the process of talent identification are fully aware of the physical advantages afforded to those born early in the selection year particularly in the younger age groups.

Based on the self-assessment method of sexual maturity using Tanner’s stages of development (Tanner, 1962) a large chronological age range within each stage of pubic hair development for elite young players in professional English soccer academies was found (Chapter 7.2). The fact that players in English soccer academies are grouped by chronological age irrespective of biological maturity means that some misclassification of players in relation to their biological maturity is inevitable. In the present study significant improvements in physical performance were found with increasing stage of maturity, further analysis suggested that standing height and body mass were the most significant contributors to performance variation between stages of maturity (Chapter 7.2). Given the large potential variation in maturity status of players within the same age group (Chapter 7.2), coaches must consider stage of maturity and not only chronological age in order to develop a comprehensive assessment and therefore understanding of the physical performance level of their players.

10.4 KEY PRACTICAL APPLICATION

The fact that the pattern in the rate of change in agility was different to that in all other variables (Chapter 8.0) in addition to agility being the key discriminating physical performance characteristic of academy players who went on to gain professional contracts (Chapter 9.4) would appear to have important ramifications for practitioners working with elite young players. Firstly, these findings highlight the importance of making an accurate assessment of players' agility, especially in the youngest age groups when players' are initially recruited into the academy system. This will allow players' with outstanding physical ability to be highlighted as well as identifying a potential weakness in a player's physical performance which could be addressed through appropriate training interventions from an early age. Secondly, best practice must warrant the inclusion of physical training programmes which focus on developing a player's agility. Such programmes should be instigated with the yougest players' where the largest improvements in agility performance have been observed to occur.

10.5 SUMMARY

The basis of this thesis has been to further the understanding of physical performance in relation to the elite youth soccer player. This research process has involved the largest and most comprehensive investigation of its kind to date, both in terms of the number of elite young players (2,252) and the range of age groups (U9s to U19s) studied. The scale of the research undertaken and the range of relevant topics that have been analysed, from ethnicity to the relative age effect provide a more complete understanding of the physical development, and progression to professional soccer, of elite child and adolescent academy players. The key finding of the thesis is that agility is the most important physical characteristic distinguishing between different groups of players including those who do and those who do not go on to sign a professional contract.

10.6 RESEARCH LIMITATIONS

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

1. All physical performance testing at the football academies was carried out during the evening training sessions. In order to conduct the testing during training the battery of physical performance tests was designed to enable a squad of players to be tested in approximately 1 hour. Given this time constraint during which the test battery could be administered there was a limit to the number and type of tests which could be administered. For example, despite repeated sprinting ability being recognised as an important physical capacity in modern soccer (Stolen et al., 2005) no such test was included in the test battery employed in the current study because of the time constraint on testing administration.

2. The longitudinal analysis of the elite players' development (Chapter 8) was based on data collected over the course of the 2002-2003, 2003-2004 and 2004-2005 playing seasons. Each age group squad was tested on 2 occasions approximately 6 months apart during each of the playing seasons outlined above. Due to the large scale of the study in which twelve academies were involved it was only logistically possible to timetable two evenings each season during which respective age group squads could be tested. Consequently if a player missed the scheduled testing session due to injury or absence from training the opportunity to collect data on the individual player in question was lost. This is one reason why the number of testing sessions completed by subjects included in the longitudinal analysis ranged between 1 and 6 testing sessions during the 3 seasons in which the data collection took place.

3. The research project was only funded for three years of data collection. Multilevel modelling analysis was then undertaken with this data to provide an understanding of developmental changes in physical performance in elite child and adolescent soccer players. At the time of the study players attended academies from U9 to U19 years of age. Based on this it would have been ideal to follow players throughout their academy careers, from U9 to U19 years of age to provide a more indepth understanding of the developmental changes in physical performance that take place.

4. Ten professional clubs agreed to take part in the research project. However, because of a change in personel and/or coaching philosophy two of the ten clubs withdrew from the project after the first year of data collection. These clubs were replaced with two other clubs for the second and third year of data collection. Therefore three years of data was only collected at eight clubs. Furthermore, because of ethical concerns only two of the clubs were willing to take part in the sexual maturation aspect of the project.

10.7 RECOMMENDATIONS FOR FUTURE RESEARCH

The findings established within this thesis provide an overview of the physical performance characteristics of elite youth soccer players. On the basis of the current findings recommendations for future research in this subject area are made.

1. Expanding the current research to provide a comparison with elite academy players in other countries.
2. Assessing the effect of the English academy system on players' physical development.
3. Assessment of specific training interventions to improve physical performance in elite young players.

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APPENDIX A

Our Ref: MH/HJE/PROPRESEARCH

20th March 2002

Joe Bloggs
Tottenham Hotspur FC
Bill Nicholson Way
748 High Road
Tottenham
London
N17 0AP

Dear Kunle

Re: Physical and Physiological Performance Measures in Elite Young Players

As part of the ever expanding remit of this department we have acquired funding to conduct a three year prospective study to establish normative physical/physiological values of elite young players over a range of 11 age groups (9-19 years). There are several aims of this work and we feel it will be of great benefit to the football industry, especially those involved in youth player development.

The tests we envisage to use are basic and easy to administer, however we would value your thoughts due to the extensive experience you have in the profession. It is expected that 10 Academies will be invited to participate in the research, the testing being conducted by the football association with the support of club staff. It is hoped, however, that the selected tests can also be conducted by those clubs who are not involved in the study for their own interest.

Approximately six tests are being proposed:

1. Acceleration: standing start from 0-5m
2. Maximum velocity: rolling start measuring from 25-30m
3. Power aspects: counter movement jump and rocket jump
4. Endurance: bleep test or yo-yo intermittent endurance test
5. Speed endurance: repeated sprint test, limited recovery – various courses
6. Agility test: various courses

Your comments on the above would be greatly appreciated and your thoughts on the suitability of these tests and other aspects that hopefully you will consider, such as equipment; for sprint tests and various jumping tests the Newtest equipment has been used by this department, however any thoughts you have on the suitability of other equipment would be appreciated.

Your opinion will be highly valued and hopefully help produce an excellent piece of practical research to enhance the scientific support in professional football. I would be grateful if you could use the enclosed form to return any comments you may have.

Thank you for your support

Kind regards.

Yours sincerely

Mark Hulse
Exercise Scientist
The Football Association

Enc.

APPENDIX B

- COMMENTS FORM -

PROPOSED EXERCISE SCIENCE RESEARCH

ESTABLISHING PHYSICAL/PHYSIOLOGICAL NORMATIVE VALUES IN ELITE YOUNG PLAYERS

TESTING AREAS

Acceleration:

Maximum Velocity:

Power:

Endurance:

Speed Endurance:

Agility:

Additional Comments:

Please return this form to The FA Medical & Exercise Science Department using
the enclosed pre-paid envelope.

Thank you

APPENDIX C

18th September 2002

Dear Club Exercise Scientist/Conditioning Coach

RE: THE FOOTBALL ASSOCIATION PERFORMANCE TESTING RESEARCH IN PROFESSIONAL FOOTBALL ACADEMIES

- **PARENT/GUARDIAN INFORMATORY LETTER**

The current research programme relating to performance testing in professional football academies involves academy players from U9 – U19 at 10 academies. It is necessary to obtain written consent from these players. However, since there are players aged under 16 who are involved in the performance testing research it is necessary to obtain written consent from the parent/guardian of these players.

The Football Association Medical and Exercise Science Department has been advised that whilst written consent is not required from the parents/guardians of players aged over 16, the Club Exercise Scientist/Conditioning Coach should inform those parents/guardians concerned that performance test data is being collected by The Football Association Medical and Exercise Science Department for research purposes only.

A brief informative letter for the Club Exercise Scientist/Conditioning Coach to issue to the parents/guardians of these Academy Players has been prepared and is enclosed together with the two types of Consent/Disclaimer/Release of Information Forms.

Kind regards.

Yours sincerely

Mark Hulse
Exercise Scientist
The Football Association.

Encs.

APPENDIX D
Date as Postmark

Dear Parent/Guardian

RE: THE FOOTBALL ASSOCIATION PERFORMANCE TESTING RESEARCH IN PROFESSIONAL FOOTBALL ACADEMIES

♦ **PARENT/GUARDIAN INFORMATORY LETTER**

The Football Association has agreed to fund a Performance Testing Research Programme involving all players in 10 selected professional football academies. In order for the exercise science and conditioning profession to continue to make progress in football at all levels, it is important that normative performance values are established.

All performance testing data will be collected by a member of staff from The Football Association together with the Club Exercise Scientist/Conditioning Coach. The information will be used solely for research purposes by The Football Association Medical and Exercise Science Department.

The Performance Testing Research Programme is a very proactive initiative that is aimed at assisting in the development of conditioning in academy players and ultimately enhancing the development of your son. The aims of conducting the Performance Testing Research are many, some of which are stated below:

- **To provide normative values of performance tests at all ages in professional football academies;**
- **To provide important information about players and in conjunction with the medical research projects being undertaken allude to the injury potential of players with certain attributes;**
- **To assist in the delivery of suitable conditioning programmes for players at specific stages of athletic development;**

- **To assist clubs in assessing the effectiveness of their own programmes compared to performance measures in other academies; and**
- **To enhance levels of awareness and contribute to the delivery of educational material within the football industry.**

If your son is over sixteen years of age, he will be asked to sign a Consent/Disclaimer/Release of Information Form, prior to the commencement of The Football Association Performance Testing Research Project. If your son is under 16 years of age you, as the parent/guardian, will be asked to sign a Consent/Disclaimer/Release of Information Form.

The Football Association felt it important that as parents/guardians you were informed and given details of the Performance Testing Research Programme, with the knowledge that the welfare of your son is regarded as a high priority by all concerned.

Should you have any queries or comments about the Performance Testing you are asked to refer them to your son's Club Exercise Scientist/Conditioning Coach.

With kind regards

Yours sincerely

Mark Hulse
Exercise Scientist,

The Football Association.

APPENDIX E

TEST INFORMATION FOR PLAYERS AND PARENTS/GUARDIANS

Field Tests: Introduction

These tests aim to measure many of the things that are important for your performance in a game of football, including, speed, power, agility, strength etc. You will perform these field tests in a sports hall at your club. The tests that you will perform includes:

1. **20m Multi-Stage Fitness Test Warm Up** - This test acts as a warm up and involves running over a 20m distance. You will need to run in time to

an audio signal (a 'bleep') which indicates when you should be at the end of each 20 m. You will need to turn at the end of the 20 m then begin the next 20m. You will be required keep time to the 'bleeps' until you reach the appropriate level for your age group. During this test you will wear a heart rate monitor that will record your heart rate as it goes up during the test and comes down after the test.

2. **Vertical Jump Test** – You will be asked to perform three jumps on a jump mat that measures how high you are able to jump.

3. **10m and 20m** Sprint - You will run as fast as you can between two timing gates set 10m and 20m from a standing start.

4. **Slalom Agility** Test – You will run as fast as possible through a zig-zag course over approximately 20m.

Other Measurements

Some other information will be collected from you at the testing session, including:

- Height and weight
- Playing position
- Ethnic origin and nationality
- Self-assessment of maturity (see details below)

Self-Assessment of Maturity

The reason for this assessment is that young people of the same age can be at very different stages of maturity, e.g. 13-14 year old boys may look slim and slight or tall and thicker-set depending on whether or not they have gone through puberty. It is a better comparison to examine the performance results of young people of the same maturity rather than of the same age. The assessment procedure is done in privacy and requires you to carefully study some pictures of different stages of development (e.g. genital development and amount of pubic hair) and decide which picture most closely matches your own stage of development. You write the number of that picture down on the form, place the form in the coded envelope and seal it handing the envelope to the person leading the testing.

APPENDIX F

THE FOOTBALL ASSOCIATION PERFORMANCE TESTING RESEARCH IN PROFESSIONAL FOOTBALL ACADEMIES

Academy Player Consent/Disclaimer/Release of Information Form

I hereby declare that The Football Association Performance Testing Research has been fully explained to me to my satisfaction by the Club Exercise Scientist/Conditioning Coach.

Signed:…………………………………………….
Name (print):…………………………………….

CONSENT SECTION

I fully consent to taking part in The Football Association Performance Testing Research and that the test results attained by me may be utilised for research purposes (please sign where applicable):

Signed:…………………………………………….
Name (print):…………………………………….
Date:……………………………………………….

DISCLAIMER SECTION

I have been offered but do not wish to take part in The Football Association Performance Testing Research (please sign where applicable):

Signed:…………………………………………….
Name (print):…………………………………….
Date:……………………………………………….

RELEASE OF INFORMATION SECTION

This section concerns the disclosure of reports (in the form of test data) by the Club Exercise Scientist/Conditioning Coach to The Football Association Medical and Exercise Science Department:

THE FOOTBALL ASSOCIATION DISCLOSURE

I hereby give my consent for the Club Exercise Scientist/Conditioning Staff to supply confidential performance test results to The Football Association Medical and Exercise Science Department and acknowledge that information contained in that report may be used for exercise science research and statistical analysis purposes provided always that personal references shall not be made in any report or other published material.

Signed (*Parent/Guardian)*:…………………………………………………….
Name (*Please Print*):……………………………………………………..
Date:………………………………….

APPENDIX G

THE FOOTBALL ASSOCIATION PERFORMANCE TESTING RESEARCH IN PROFESSIONAL FOOTBALL ACADEMIES

Academy Player Parent/Guardian Consent/Disclaimer/Release of Information Form

I hereby declare that The Football Association Performance Testing Research has been fully explained to me to my satisfaction by the Club Exercise Scientist/Conditioning Coach.

Signed (*Parent/Guardian)*:………………………………………………….
Name (*Please Print*):………………………………………………………….

CONSENT SECTION

I fully consent to my son (name - please print) **……………………………………………………**

taking part in The Football Association Performance Testing Research and that the test results attained by my son may be utilised for research purposes (please sign where applicable):

Signed (*Parent/Guardian)*:………………………………………………….
Name (*Please Print*):…………………………………………………………...

DISCLAIMER SECTION

My son (name - please print) **………………………………………………………………………**

has been offered but does not wish to take part in The Football Association Performance Testing

Research (please sign where applicable):

RELEASE OF INFORMATION SECTION

This section concerns the disclosure of reports (in the form of test data) by the Club Exercise Scientist/Conditioning Coach to The Football Association Medical and Exercise Science Department:

THE FOOTBALL ASSOCIATION DISCLOSURE

I hereby give my consent for the Club Exercise Scientist/Conditioning Staff to supply confidential performance test results to The Football Association Medical and Exercise Science Department and acknowledge that information contained in that report may be used for exercise science research and statistical analysis purposes provided always that personal references shall not be made in any report or other published material.

Signed (*Parent/Guardian)*:………………………………………………….
Name (*Please Print*):………………………………………………………..
Date:

APPENDIX H
PLAYER INFORMATION DATA COLLECTION SHEET

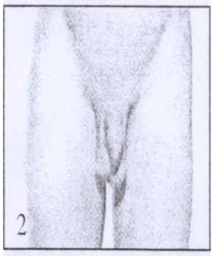
CLUB:____________________ **SQUAD:**____________________ **DATE:**____________

NAME	**DATE OF BIRTH**	**ETHNICITY**	**NATIONALITY**	**INTERNATIONAL PLAYERS**	**PLAYING POSITION**	**STANDING HEIGHT** (cm)	**BODYWEIGHT** (kg)

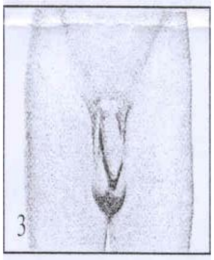
APPENDIX I

Stage 1
(no picture)

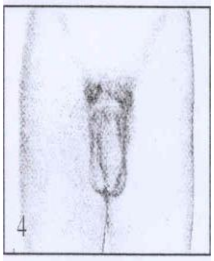
Stage 1 (no picture): There is no pubic hair at all.



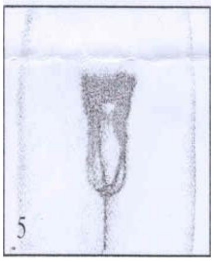
Stage 2: There is a little soft hair. Most of the hair is at the base of the penis. This hair may be straight or a little curly.



Stage 3: The hair is darker in this stage. It is coarser and more curled. It has spread out and thinly covers the area around the penis.



Stage 4: The hair is now as dark as that of an adult man. However, the area it covers not as large as that of an adult man. The hair has not spread out to touch the thighs.



Stage 5: The hair has spread out to touch the thighs. The hair is now like that of an adult man. It also covers the same area as that of an adult man and has the shape of a triangle (V).

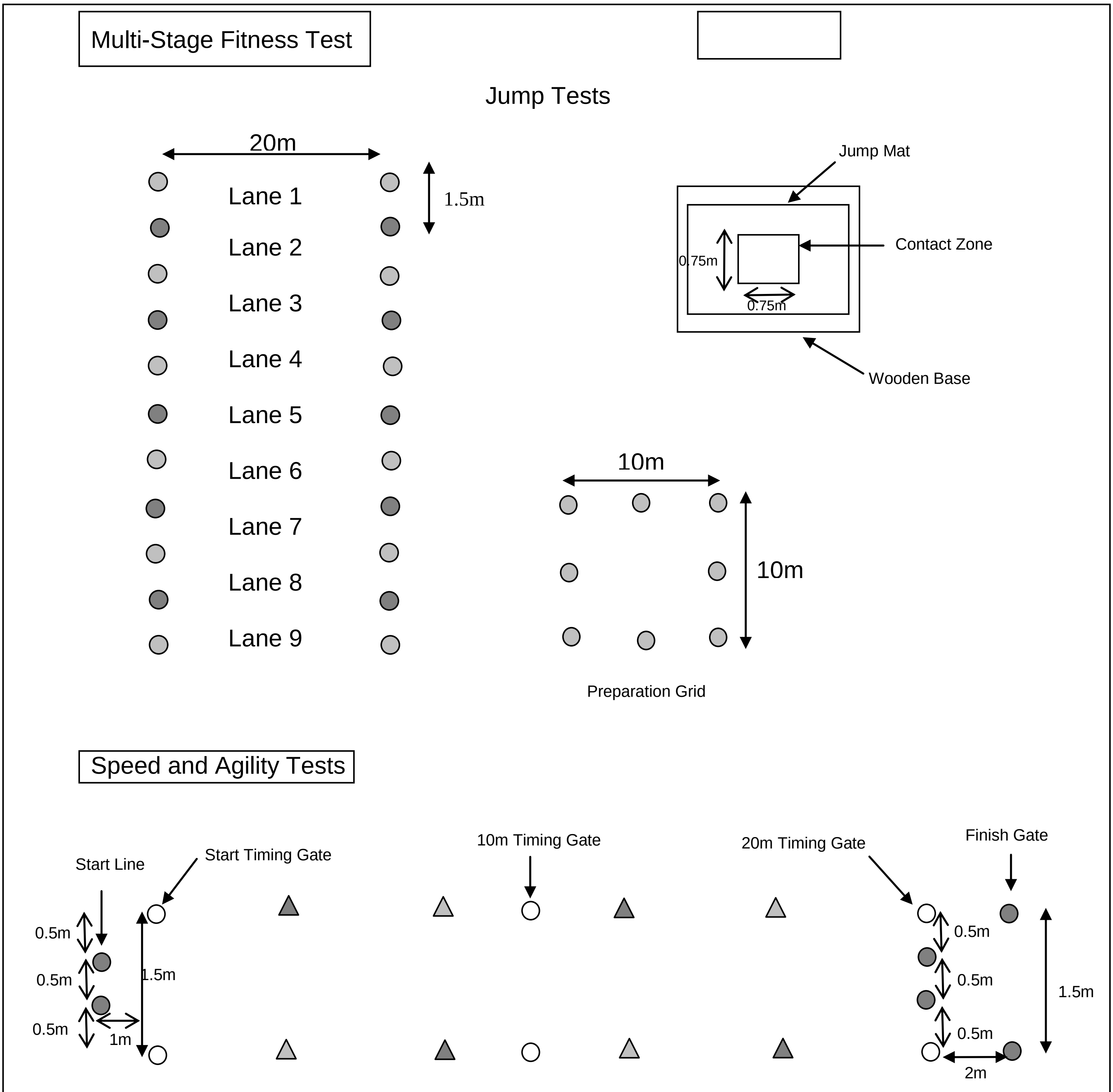
APPENDIX J

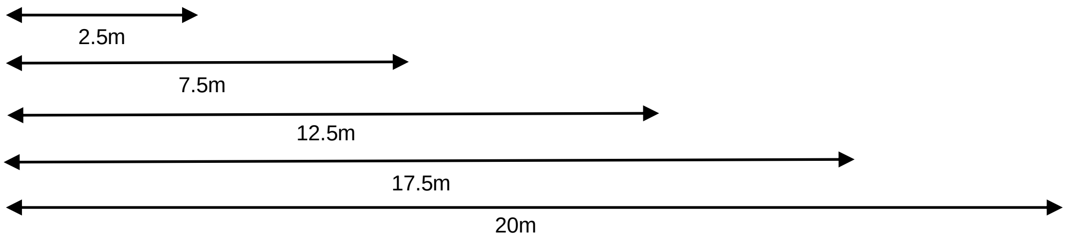
Tanner Stages – Male Pubic Hair Development Response Form

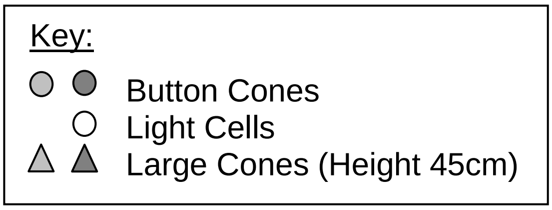
STAGE 1	**STAGE 2**	**STAGE 3**	**STAGE 4**	**STAGE 5**

APPENDIX K

Plan of Testing Set-Up (nb. not to scale)




2.5m
7.5m
12.5m
17.5m
20m


Key:
Button Cones
Light Cells
Large Cones (Height 45cm)

APPENDIX L

PERFORMANCE TESTING DATA COLLECTION SHEET

CLUB: ______________________ **SQUAD:** ______________________ **DATE:** ______________________

Player	Bleep Test	Jump Tests									Speed Test				Agility Test		*Notes*
		Rocket Jump			CMJ (without arms)			CMJ (with arms)			Run 1		Run 2		Run 1	Run 2	
	Strap Number	Height (cm)			Height (cm)			Height (cm)			10m (sec)	20m (sec)	10m (sec)	20m (sec)	(sec)	(sec)	

For enquiries/clarification please contact Mark Hulse on – **Telephone:** 0207 745 4960 **Email:** mark.hulse@the-fa.org **Fax:** 0207 745 5960

APPENDIX M

BLEEP TEST RECORD SHEET

LEVEL	SHUTTLE															
1	1	2	3	4	5	6	7									
2	1	2	3	4	5	6	7	8								
3	1	2	3	4	5	6	7	8								
4	1	2	3	4	5	6	7	8	9							
5	1	2	3	4	5	6	7	8	9							
6	1	2	3	4	5	6	7	8	9							
7	1	2	3	4	5	6	7	8	9	10						
8	1	2	3	4	5	6	7	8	9	10						
9	1	2	3	4	5	6	7	8	9	10	11					
10	1	2	3	4	5	6	7	8	9	10	11					
11	1	2	3	4	5	6	7	8	9	10	11	12				
12	1	2	3	4	5	6	7	8	9	10	11	12				
13	1	2	3	4	5	6	7	8	9	10	11	12	13			
14	1	2	3	4	5	6	7	8	9	10	11	12	13			
15	1	2	3	4	5	6	7	8	9	10	11	12	13			
16	1	2	3	4	5	6	7	8	9	10	11	12	13	14		
17	1	2	3	4	5	6	7	8	9	10	11	12	13	14		
18	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
19	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
20	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
21	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

SUBJECT	LEVEL	SUBJECT	LEVEL

APPENDIX N

Ref. No: …………

Physical Performance in Football – Analysis and Measurement

AIM: *An assessment of coaches opinions towards physical performance in football. All questions are strictly confidential. Please be as truthful as possible and only tick one box per question unless otherwise indicated. Thank you for your co-operation*

PERSONAL DETAILS

PART A:

1. **SEX:** Male ❑ Female ❑

2. **AGE:** 0 – 20 Years ❑ 21 – 30 years ❑ 31 – 40 years ❑
41 – 50 Years ❑ 51 – 60 years ❑ 61 – 70 years ❑
70 years+ ❑

3. **POSITION AT CLUB:**
1st Team Coach ❑ Reserve Team Coach ❑ Youth/Academy Coach ❑

4. **HIGHEST COACHING QUALIFICATION:**
UEFA Pro-Licence ❑ UEFA 'A' Licence ❑ Other ❑ (please specify)
UEFA 'B' Licence ❑ UEFA 'C' Licence ❑ ……………………………

5. **COACHING EXPERIENCE:**
0 – 2 years ❑ 3 – 5 years ❑ 6 – 10 years ❑
11 – 20 years ❑ 21+ years ❑

For the purpose of this questionnaire please use the following definitions:-

Strength: the ability to produce forceful actions and overcome opponents resistance in a game.
Endurance: the ability to maintain a high work rate throughout a game.
Speed: the ability to accelerate and run quickly over short distances (0 – 30 metres).
Power: the ability to perform strong movements at speed eg. jumping etc.
Speed Endurance: the ability to perform repeated sprints with little rest in between.
Balance/Co-ordination: the ability to control quick changes of movement.
Agility: the ability to change direction at speed.

PART B:

6. List in order of importance the attributes of an elite player. (1 – Most important to 4 – Least important)

Physical/Physiological		Psychological	
Technical		Social	

7. What do you consider the important physical attributes of an elite player. (Please circle your response).

	Don't Know	Not at all Important	Not really Important	Slightly Important	Important	Very Important
Strength	**0**	**1**	**2**	**3**	**4**	**5**
Endurance	**0**	**1**	**2**	**3**	**4**	**5**
Speed	**0**	**1**	**2**	**3**	**4**	**5**
Power	**0**	**1**	**2**	**3**	**4**	**5**
Speed Endurance	**0**	**1**	**2**	**3**	**4**	**5**
Balance / Co-Ordination	**0**	**1**	**2**	**3**	**4**	**5**
Agility	**0**	**1**	**2**	**3**	**4**	**5**

8. Does the relative importance of the various physical components differ between different positions?

Yes ❑ No ❑ Don't Know ❑

If 'yes' what importance would you place on the various physical attributes for the following positions? (Please circle your response).

GOALKEEPER

	Don't Know	Not at all Important	Not really Important	Slightly Important	Important	Very Important
Strength	**0**	**1**	**2**	**3**	**4**	**5**
Endurance	**0**	**1**	**2**	**3**	**4**	**5**
Speed	**0**	**1**	**2**	**3**	**4**	**5**
Power	**0**	**1**	**2**	**3**	**4**	**5**
Speed Endurance	**0**	**1**	**2**	**3**	**4**	**5**
Balance / Co-Ordination	**0**	**1**	**2**	**3**	**4**	**5**
Agility	**0**	**1**	**2**	**3**	**4**	**5**

FULL BACK

	Don't Know	Not at all Important	Not really Important	Slightly Important	Important	Very Important
Strength	**0**	**1**	**2**	**3**	**4**	**5**
Endurance	**0**	**1**	**2**	**3**	**4**	**5**
Speed	**0**	**1**	**2**	**3**	**4**	**5**
Power	**0**	**1**	**2**	**3**	**4**	**5**
Speed Endurance	**0**	**1**	**2**	**3**	**4**	**5**
Balance / Co-Ordination	**0**	**1**	**2**	**3**	**4**	**5**
Agility	**0**	**1**	**2**	**3**	**4**	**5**

CENTRE BACK

	Don't Know	Not at all Important	Not really Important	Slightly Important	Important	Very Important
Strength	**0**	**1**	**2**	**3**	**4**	**5**
Endurance	**0**	**1**	**2**	**3**	**4**	**5**
Speed	**0**	**1**	**2**	**3**	**4**	**5**
Power	**0**	**1**	**2**	**3**	**4**	**5**
Speed Endurance	**0**	**1**	**2**	**3**	**4**	**5**
Balance / Co-Ordination	**0**	**1**	**2**	**3**	**4**	**5**
Agility	**0**	**1**	**2**	**3**	**4**	**5**

MIDFIELD

	Don't Know	Not at all Important	Not really Important	Slightly Important	Important	Very Important
Strength	**0**	**1**	**2**	**3**	**4**	**5**
Endurance	**0**	**1**	**2**	**3**	**4**	**5**
Speed	**0**	**1**	**2**	**3**	**4**	**5**
Power	**0**	**1**	**2**	**3**	**4**	**5**
Speed Endurance	**0**	**1**	**2**	**3**	**4**	**5**
Balance / Co-Ordination	**0**	**1**	**2**	**3**	**4**	**5**
Agility	**0**	**1**	**2**	**3**	**4**	**5**

FORWARD

	Don't Know	Not at all Important	Not really Important	Slightly Important	Important	Very Important
Strength	**0**	**1**	**2**	**3**	**4**	**5**
Endurance	**0**	**1**	**2**	**3**	**4**	**5**
Speed	**0**	**1**	**2**	**3**	**4**	**5**
Power	**0**	**1**	**2**	**3**	**4**	**5**
Speed Endurance	**0**	**1**	**2**	**3**	**4**	**5**
Balance / Co-Ordination	**0**	**1**	**2**	**3**	**4**	**5**
Agility	**0**	**1**	**2**	**3**	**4**	**5**

9. How important is the factor of physical/physiological attributes in determining, the following? (please circle your response).

	Don't Know	Not at all Important	Not really Important	Slightly Important	Important	Very Important
If a player gets a professional contract	**0**	**1**	**2**	**3**	**4**	**5**
If a player is selected to play international football	**0**	**1**	**2**	**3**	**4**	**5**
If a player is injury prone	**0**	**1**	**2**	**3**	**4**	**5**
If a player performs well in tournaments	**0**	**1**	**2**	**3**	**4**	**5**
If a player is technically accomplished	**0**	**1**	**2**	**3**	**4**	**5**
If a player can fulfil tactical demands	**0**	**1**	**2**	**3**	**4**	**5**
If a player can play above his age group	**0**	**1**	**2**	**3**	**4**	**5**

10. Do you think that the physical/physiological attributes of international players are different to those of club players?

Yes ❑ No ❑ Don't Know ❑

If 'yes' in what ways do you feel that the physical/physiological attributes of international and club players are different based on the following statements?

	Don't Know	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
International Players are stronger						
International players have better endurance						
International Players are faster						
International Players are more powerful						
International Players have better speed endurance						
International Players have better Balance/co-ordination						
International players are more agile						

11. Do you think that a players physical/physiological attributes are more important in the modern game than they have been over the past 30 years?

Yes ❑ No ❑ Don't Know ❑

If 'yes', in what way do you think players physique and physical qualities have changed over the past 30 years.

	Don't Know	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Players have become bigger (height and weight)						
Players have become stronger						
Players have become faster						
Players now have better endurance						
Players have become more resistant to injury						
Players have become more agile						
Players have become more powerful						
Players now have better speed endurance						
Players have become more balanced/co-ordinated						

12. Do you think players from certain ethnic backgrounds are naturally more physically able, (faster, stronger, etc.) in comparison to other players?

Yes ❑ No ❑ Don't Know ❑

If 'yes', from what ethnic groups do you feel that players are naturally more physically advanced? (tick all those that apply)

White	
Black Caribbean	
Black African	
Chinese	
Indian	
Black Other	
Pakistani	
Other	

APPENDIX P

Ref. No: …………

Physical Performance in Football – Analysis and Measurement

AIM: *An assessment of players opinions towards physical performance in football. All questions are strictly confidential. Please be as truthful as possible and only tick one box per question unless otherwise indicated. Thank you for your co-operation*

PERSONAL DETAILS

PART A:

1. Sex: Male ❑ Female ❑

2. Age: U9 ❑ U10 ❑ U11 ❑ U12 ❑ U13 ❑ U14 ❑ U15 ❑ U16 ❑ U17 ❑ U18 ❑ U19 ❑ Senior ❑

3. Highest playing standard: Club ❑ International ❑

For the purpose of this questionnaire please use the following definitions:-

Strength: the ability to produce forceful actions and overcome opponents resistance in a game.
Endurance: the ability to maintain a high work rate throughout a game.
Speed: the ability to accelerate and run quickly over short distances (0 – 30 metres).
Power: the ability to perform strong movements at speed eg. jumping etc.
Speed Endurance: the ability to perform repeated sprints with little rest in between.
Balance/Co-ordination: the ability to control quick changes of movement.
Agility: the ability to change direction at speed.

PART B:

4. List in order of importance the attributes of an elite player. (1 – Most important to 4 – Least important)

Physical/Physiological		Psychological	
Technical		Social	

5. What do you consider the important physical attributes of an elite player. (Please circle your response).

	Don't Know	Not at all Important	Not really Important	Slightly Important	Important	Very Important
Strength	**0**	**1**	**2**	**3**	**4**	**5**
Endurance	**0**	**1**	**2**	**3**	**4**	**5**
Speed	**0**	**1**	**2**	**3**	**4**	**5**
Power	**0**	**1**	**2**	**3**	**4**	**5**
Speed Endurance	**0**	**1**	**2**	**3**	**4**	**5**
Balance / Co-Ordination	**0**	**1**	**2**	**3**	**4**	**5**
Agility	**0**	**1**	**2**	**3**	**4**	**5**

6. Does the relative importance of the various physical components differ between different positions?

Yes ❑ No ❑ Don't Know ❑

If 'yes' what importance would you place on the various physical attributes for the following positions? (Please circle your response).

GOALKEEPER

	Don't Know	Not at all Important	Not really Important	Slightly Important	Important	Very Important
Strength	0	1	2	3	4	5
Endurance	0	1	2	3	4	5
Speed	0	1	2	3	4	5
Power	0	1	2	3	4	5
Speed Endurance	0	1	2	3	4	5
Balance / Co-Ordination	0	1	2	3	4	5
Agility	0	1	2	3	4	5

FULL BACK

	Don't Know	Not at all Important	Not really Important	Slightly Important	Important	Very Important
Strength	0	1	2	3	4	5
Endurance	0	1	2	3	4	5
Speed	0	1	2	3	4	5
Power	0	1	2	3	4	5
Speed Endurance	0	1	2	3	4	5
Balance / Co-Ordination	0	1	2	3	4	5
Agility	0	1	2	3	4	5

CENTRE BACK

	Don't Know	Not at all Important	Not really Important	Slightly Important	Important	Very Important
Strength	0	1	2	3	4	5
Endurance	0	1	2	3	4	5
Speed	0	1	2	3	4	5
Power	0	1	2	3	4	5
Speed Endurance	0	1	2	3	4	5
Balance / Co-Ordination	0	1	2	3	4	5
Agility	0	1	2	3	4	5

MIDFIELD

	Don't Know	Not at all Important	Not really Important	Slightly Important	Important	Very Important
Strength	0	1	2	3	4	5
Endurance	0	1	2	3	4	5
Speed	0	1	2	3	4	5
Power	0	1	2	3	4	5
Speed Endurance	0	1	2	3	4	5
Balance / Co-Ordination	0	1	2	3	4	5
Agility	0	1	2	3	4	5

FORWARD

	Don't Know	Not at all Important	Not really Important	Slightly Important	Important	Very Important
Strength	0	1	2	3	4	5
Endurance	0	1	2	3	4	5
Speed	0	1	2	3	4	5
Power	0	1	2	3	4	5
Speed Endurance	0	1	2	3	4	5
Balance / Co-Ordination	0	1	2	3	4	5
Agility	0	1	2	3	4	5

7. How important is the factor of physical/physiological attributes in determining, the following? (please circle your response).

	Don't Know	Not at all Important	Not really Important	Slightly Important	Important	Very Important
If a player gets a professional contract	0	1	2	3	4	5
If a player is selected to play international football	0	1	2	3	4	5
If a player is injury prone	0	1	2	3	4	5
If a player performs well in tournaments	0	1	2	3	4	5
If a player is technically accomplished	0	1	2	3	4	5
If a player can fulfil tactical demands	0	1	2	3	4	5
If a player can play above his age group	0	1	2	3	4	5

8. Do you think that the physical/physiological attributes of international players are different to those of club players?

Yes ❑ No ❑ Don't Know ❑

If 'yes' in what ways do you feel that the physical/physiological attributes of international and club players are different based on the following statements?

	Don't Know	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
International Players are stronger						
International players have better endurance						
International Players are faster						
International Players are more powerful						
International Players have better speed endurance						
International Players have better Balance/co-ordination						
International players are more agile						

9. Do you think that a players physical/physiological attributes are more important in the modern game than they have been over the past 30 years?

Yes ❑ No ❑ Don't Know ❑

If 'yes', in what way do you think players physique and physical qualities have changed over the past 30 years.

	Don't Know	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Players have become bigger (height and weight)						
Players have become stronger						
Players have become faster						
Players now have better endurance						
Players have become more resistant to injury						
Players have become more agile						
Players have become more powerful						
Players now have better speed endurance						
Players have become more balanced/co-ordinated						

10. Do you think players from certain ethnic backgrounds are naturally more physically able, (faster, stronger, etc.) in comparison to other players?

Yes ❑ No ❑ Don't Know ❑

If 'yes', from what ethnic groups do you feel that players are naturally more physically advanced? (tick all those that apply)

White	
Black Caribbean	
Black African	
Chinese	
Indian	
Black Other	
Pakistani	
Other	