Physical development and match analysis of elite youth soccer players

by

Heita Goto

A Doctoral Thesis

Submitted in partial fulfilment of the requirements for the award of Doctor of Philosophy of Loughborough University

May 2012

Abstract

This thesis examined the physical development and match performance of elite youth academy soccer players some of whom were likely to progress to become professional soccer players. Physical characteristics such as standing height, body mass and estimated body fat composition, physical performance and match performance were explored. Furthermore, the relationships between physical performance and match running performance were examined in players from the U9 to U18 age group squads. Finally, the influence of biological maturity on physical characteristics, physical performance and match running performance in these elite youth soccer players was investigated and recommendations are made concerning talent identification and player development.

One hundred and eighty-three elite soccer players (chronological age: 8.9 to 18.7 years; age grouping U9-U18) from an English Premier League Academy in the East Midlands were assessed for standing height, body mass, skinfolds, 30 m sprint, slalom and 505 agility, squat jump, counter movement jump with and without arms, Yo-Yo intermittent recovery test (level 1) and Multi-stage fitness test. All physical and performance variables measured in the study developed over time with chronological age except for the sum of 4 skinfold sites and estimated body fat composition (squad mean ± SD, U9 vs. U17: standing height, 139.4 ± 4.8 cm vs. 181.3 ± 5.6 cm; body mass, 33.6 ± 3.9 kg vs. 72.6 ± 5.7 kg; 30 m sprint, 5.26 ± 0.25 vs. 4.15 ± 0.11 s; slalom agility test, 4.83 ± 0.25 vs. 3.96 ± 0.09 s; counter movement jump with arms, 30 ± 3 cm vs. 48 ± 6 cm; the Yo-Yo intermittent recovery test (level 1), 787 ± 333 vs. 2617 ± 573 m). Standing height, body mass, 10, 15, and 30 m sprint times, performance on both agility tests, performance of squat jump and counter movement jump with arms; performance on the Yo-Yo intermittent recovery test (level 1) and on Multi-stage fitness test continued developing until the players reached the U17 squad. Moreover, the highest rate of development in standing height, body mass and all physical fitness tests occurred between the U9-U13 squads.

Distance run during match play by 9 to 16 year old boys varied from 4056 (U9) to 7697 (U16) m per match ($p < 0.05$), and varied from 4675 to 6727 $m \cdot hour^{-1}$ of a match ($p < 0.05$). The U11-U16 squads covered a greater distance by high speed running (range: 487-553 $m \cdot hour^{-1}$) compared to the U9 (178 $m \cdot hour^{-1}$) and U10 (219 $m \cdot hour^{-1}$) squads ($p < 0.05$ for all). Similarly, the percentage of time spent in high speed running by the U9 (1.1 %) and U10 (1.3 %) squads was less than that seen in the U11-U16 (2.6-3.0 %) squads ($p < 0.05$ for all).

Chronological age accounted for 43% ($p < 0.01$), and the Multi-stage fitness test performance explained 7% ($p < 0.05$) of the variance in total distance covered per hour of a match in the U11-U16 group. Chronological age ($p < 0.01$) and the Multi-stage fitness test performance ($p < 0.05$) accounted for 10% and 11% respectively of the variance in percentage of time spent in moderate speed running. Chronological age accounted for 11 % of the variance in the percentage of time spent in high speed running ($p < 0.01$), whereas 30 m sprint and the Multi-stage fitness test performances explained 15% and 8% respectively of the variance in percentage of time spent in high speed running ($p < 0.05$ for both). The U9 and U10 squads showed a positive relationship between 20 m sprint time and distance covered in moderate speed running per hour of a match ($r = 0.54$, $p < 0.05$). In the U11-U13 squads relationships were evident between performance in 5, 10, 15, 20 and 30 m sprint ($r = -0.67$ to -0.46), the 3 standing vertical jumps ($r = 0.46$ to 0.73) and the 2 endurance tests ($r = 0.45$ to 0.60), and

distance covered by moderate and high speed running per hour of a match ($p < 0.05$ for all). However, in the U14-U16 squads no significant relationships were evident.

When stage of genital development was used to categorise players, standing height and body mass in the U12, U13 and U14 squads were positively influenced by biological maturity ($p < 0.05$ for all). The more mature players in the U13 squad also performed better in counter movement jump without arms and the Multi-stage fitness test ($p < 0.05$ for both). When stage of pubic hair development was used to categorise players, maturity status showed a positive influence on standing height and slalom agility test performance in the U12 squad ($p < 0.05$ for both) and on standing height and body mass in the U14 squad ($p < 0.05$ for both). When estimated chronological age at peak height velocity was used to categorise players, earlier maturing players were heavier ($p < 0.01$) and performed worse in counter movement jump without arms ($p < 0.05$) than later maturers in the U9 and U10 squads. Earlier maturers were taller ($p < 0.01$), heavier ($p < 0.01$) and possessed a thicker sum of 4 skinfold sites ($p < 0.05$) and higher estimated body fat ($p < 0.01$) compared to the later maturers in the U11 and U12 squads. Moreover, early maturers covered a greater distance than late maturers in the multi-stage fitness test ($p < 0.05$) in the U13 and U14 squads. In the U15 and U16 squads, early maturers were heavier and possessed thicker sum of 4 skinfold sites and higher estimated body fat compared to the late maturers ($p < 0.01$ for all). Furthermore, early maturers possessed a thicker sum of 4 skinfold sites ($p < 0.05$), higher estimated body fat ($p < 0.01$) and covered a shorter distance during the Yo-Yo intermittent recovery test ($p < 0.01$) compared to later maturers in the U17 and U18 squads.

When stage of genital development was used to categorise players, the U12 and U13 players in stage 4 covered a greater distance in high speed running during a match than players in stage 3 ($p < 0.05$). There was a tendency for this still to be the case when distance was standardised into per hour of a match ($p = 0.065$). In the U9 and U10 squads, compared to later maturers, earlier maturers were given greater playing time during a match ($p < 0.05$), and consequently covered a greater distance during match play ($p < 0.05$). In the U13 and U14 squads, earlier maturers covered more distance per hour of a match and spent a higher percentage of time in high speed running when compared to their later maturing counterparts ($p < 0.05$ for both).

In summary this research has provided the most extensive description yet of the physical characteristics, field test performance and match performance of elite youth soccer players. In addition, for the first time the effect of biological maturity (using 3 different methods of assessment) on a wide range of field tests and on match performance has been reported. The major changes in physical characteristics, field test performance and match performance between 10 and 14 years of age suggest that coaches should avoid as many selection decisions as possible during this age period, that they should take into account the fact that match distances covered at high speeds will be affected by maturity at these ages and that they should be aware that at present, coaches choose to give more mature players additional pitch time which obviously gives them an advantage in terms of playing development. An enhanced awareness of these findings in the coaching community could lead to an improved development and more appropriate selection decisions for elite youth soccer players in England.

PREFACE

Publication

Goto, H., Morris, J.G. and Nevill, M.E. Physical activity of elite youth soccer players during match play. *Journal of Sports Sciences*. In press.

Conference Presentations

Physical activity of elite youth soccer players during match play
BASES 2010 annual conference – University of Glasgow (oral presentation)

Acknowledgement

I would like to thank my supervisors Dr. Mary Nevill and Dr. John Morris for providing me the opportunity to produce my thesis. Without their support and advice, it would have taken many years to complete my thesis. I would also like to thank my Director of research David Stensel for kind and friendly advice to improve my work.

I would like to thank Nottingham Forest Football academy for collaborating with us to complete the project. The Academy director Nick Marshall, Assistant academy director Tony Cook and Rich Meek for supporting me and creating a friendly atmosphere to make the situation easier for me to conduct my research. I would also like to thank coaches and staff at the academy for providing me some support during the data collection.

I would like to thank the players at Nottingham Forest Football Academy. Without their continuous participation in the research, I would not have sufficient data to form the thesis. They went though the tests which required short maximal bursts as well as maximal endurance on many occasions. They worked exceptionally hard in these tests and I am extremely thankful to their effort and their parents or guardians to provide transport to their children.

I would like to thank my colleagues, Vikki Leslie, Persephone Wynn, James King and Simon Cooper for supporting my data collection which took place in early morning or late evening.

I would like to thank Undergraduate and Master’s students who voluntarily assisted my data collection. Their assistance allowed me to set up the tests and keep up with the planned schedule to conduct required tests within the set time during the sessions.

I would like to thank IT support staff Ramesh Mistry and Carl Shaw for solving some problems with GPS software which was required to analyse football matches. Also, I would like to thank lab technicians John Hough and Marta Oliveira for lending me equipment for me to carry out data collection.

I would like to thank my family for supporting me throughout my PhD in many areas. Without them, I could not complete my thesis.

Contents

List of tables

List of figures

List of abbreviations

The following abbreviations are used throughout this thesis. Where they appear in text they will have been defined in the first instance:

CB (centre back)

cm (centimetre)

D (draw)

FB (fullback)

FW (forward)

G (Stage of genital development)

GK (goalkeeper)

GPS (Global Positioning System)

Hz (hertz)

kg (kilogram)

$km \cdot h^{-1}$ (kilometre per second)

L (lose)

m (metre)

m^2 (metre square)

MF (midfielder)

$m \cdot h^{-1}$ (metre per second)

min (minute)

$ml \cdot kg^{-1} \cdot min^{-1}$ (millilitre per kilogram per minute)

mm (millimetre)

$m \cdot match^{-1}$ (metre per match)

$m \cdot s^{-1}$ (metre per hour)

N (number of participants)

PH (Stage of pubic hair development)

PHV (peak height velocity)

s (second)

SD (standard deviation)

U (under, for example, U15 squad= under 15 squad)

W (win)

Chapter 1

Introduction

There has been a large volume of research examining the physical characteristics and performance of elite senior soccer players (Clark et al., 2008; Cometti et al., 2001; Dunbar and Power, 1997; Edwards et al., 2003; Impellizzeri et al., 2006; Krustrup et al., 2003; Puga et al., 1993; Rampinini et al., 2007a; Rienzi et al., 2000; Wisloff et al., 2004; Zerguini et al., 2007). This research, published between 1993 and 2008 has included measurements of: standing height, body mass, estimated body fat composition, sprint times over 10, 20 and 30 m, multiple sprint ability, agility, squat jump, counter movement jump without and with arms, leg muscle strength, estimated maximal oxygen uptake, 'lactate threshold' using a laboratory treadmill running test and the Yo-Yo intermittent recovery test level 1 and 2. Some of the studies have gone further and have separated players by their position on the pitch and have then examined the differences in physical characteristics and performance between positions (Bloomfield et al., 2004; Krustrup et al., 2003; Puga et al., 1993; Wisloff et al., 1998).

In contrast with the large volume of literature on adult players, there have been very few investigations of elite youth soccer players (defined as players who are members of a professional soccer club or national development squad, or compete at national level or higher), especially when the players are sub-divided into different age groups (Chamari et al., 2004; Helgerud et al., 2001; Hulse, 2010, unpublished; McMillan et al., 2005b; Reilly et al., 2000; Stroyer et al., 2004**)**. The few studies available have included measurements such as 30 m sprint time (Chamari et al., 2005; Malina et al., 2007; Reilly et al., 2000; Vaeyens et al., 2006**)**, estimated maximal oxygen uptake from treadmill running in a laboratory (Chamari et al., 2005; Helgerud et al., 2001; Malina et al., 2007; Reilly et al., 2000; Stroyer et al., 2004; Vaeyens et al., 2006) and a counter movement jump with the arms (Chamari et al., 2005; Helgerud et al., 2001; Hulse, 2010, unpublished; Malina et al., 2007; Reilly et al., 2000; Vaeyens et al., 2006). The players commonly recruited in these studies had a chronological age range of 12.0-18.1 years, highlighting the lack of information regarding pre-pubertal age groups (Chamari et al., 2005; Helgerud et al., 2001; Malina et al., 2007; Reilly et al., 2000;

Stroyer et al., 2004; Vaeyens et al., 2006**)**. Knowledge concerning the physical profile of elite youth players would be beneficial in talent identification, that is in terms of predicting which players might move on to a higher playing level and also in terms of developing the scientific knowledge relating to how young elite athletes progress and develop over time. Therefore, there is a need for further research examining the development of physical characteristics in elite youth soccer players.

Biological maturity is a well known factor influencing body size and physical performance (endurance, power, speed and strength) in adolescent boys. In general, games players that are advanced in terms of biological maturity are better performers than their later maturing peers (Malina et al., 2004a; Sherar et al., 2007). Also in elite youth soccer, players who were born early in the competition year are favoured more than their peers who were born later in the same year in terms of selection (Malina et al., 2004a; Carling et al., 2009). However, the players who mature late may ‘catch-up’ when they reach young adulthood and the age at which maturation occurred (early vs. late) did not lead to a difference in the percentage of players in each category who went on to become professional players (Carling et al., 2009). Therefore, it would seem to be important not to rate players largely based on physical characteristics during the period when they have a large variation in maturity level. It is also important to discover when the development in physical characteristics ceases as the concerns regarding maturational changes will not exist after this point. It has been reported that physical characteristics and physical performance including body mass, estimated body fat composition, flexibility, 30 m sprint time, multiple sprint ability and estimated maximal oxygen uptake of senior English Premier League players and 16 years olds from the same club are similar (Dunbar and Power, 1997). Hence, the development of physical characteristics and physical performance may terminate at or before the age of 16. However, this study only examined players at age 16 and senior age groups and no measurements were made on younger players and therefore the study is of limited value. No other study has examined the timing of termination in the development of physical characteristics and physical performance in elite youth soccer players. Thus there is a need for research examining the relationship between biological maturity and development of physical characteristics and physical performance of elite youth soccer players to further understanding of the impact of maturity on physically very athletic boys and to provide information which is of value to coaches and professional soccer clubs in terms of talent identification and development.

In soccer, there has been large amount of match analysis conducted on both male and female adults from amateur to elite professional players (Carling et al., 2008). A key finding has been that the distances covered at high intensity distinguish between players of differing standards (Bangsbo et al., 1991; Mohr et al., 2003) and therefore high intensity running seems to make an important contribution to match performance in soccer (Bangsbo et al., 1991; Mohr et al., 2003). Furthermore, in professional male and elite female players, a reduction in distance covered by high intensity running, which was attributed to fatigue, occurred during matches temporarily and towards the end of matches (Krustrup et al., 2005; Mohr et al., 2003). Temporary fatigue occurred after a large amount of high intensity running (Krustrup et al., 2005; Mohr et al., 2003) and fatigue towards the end of the match was thought to be due to decline in glycogen concentration in individual muscle fibres (Krustrup et al., 2006). However, there have been a limited number of match analysis studies examining youth soccer players. The studies were conducted on 11 year old Italian players (Capranica et al., 2001; Castanga et al., 2003) and, 12 and 14 years old Danish elite soccer players (three of the most successful clubs in Denmark: Stroyer et al., 2004). The mean distances covered by 11 year old Italian soccer players were 4344 m for 0-8 $km \cdot h^{-1}$, 986 m for medium intensity running, 468 m for high intensity running and 114 m for maximum intensity running (Castanga et al., 2003). Match analyses of Danish elite soccer players (three of the most successful clubs in Denmark) with a mean chronological age of 12.6 and 14.0 years showed that 31.3% and 34.0% of the match-time was spent on jogging and 7.9% and 9.0% of the match-time was spent on high intensity running (including sprinting), respectively (Stroyer et al., 2004). Match performance during the first and second halves was examined, but comparisons were only made on distance covered and, the time spent in different speed zones was not included in the analysis. Therefore, there is no information available on the match performance of 9, 10, 13, 15 and 16 year old players and, there is a very limited information available concerning high intensity running performance of elite youth players during match play. Such information would further understanding of the distances covered and the running speeds undertaken in elite youth players, providing valuable information on physiologically what elite young boys are able to achieve and practically for coaches and clubs would provide valuable information for player development and possibly talent identification.

In adult players, distance run and the time spent on different activities during a match have been shown to vary by playing position when the matches were analysed using a semiautomated video analysis (Prozone, Di Salvo et al., 2006). For example, the longest distance was covered by midfielders and the shortest distance was covered by centre backs and forwards during a match (Bradley et al., 2009; Rampinini et al., 2007b). Full backs were reported to cover a similar distance to forwards and centre backs in one study (Bradley et al., 2009) or in an earlier study a shorter distance than midfielders, but a longer distance than centre backs and forwards (Rampinini et al., 2007b). However, no studies have examined positional differences with respect to match activities in youth soccer players using GPS or video analysis. One study has examined the heart rate response to match play by position in youth soccer players and there was a tendency for a higher mean heart rate for forwards than defenders in 12 (176 vs. 174 beats·min^{-1}) and 14 (179 vs. 169 beats·min^{-1}) year old elite players (Stroyer et al., 2004). Thus, any differences in match performance according to playing position in youth soccer players have hardly been touched upon in the literature and information concerning match distances and speeds determined by GPS analysis, by position, would further understanding of the match demands of elite youth players and would provide valuable information for coaches and clubs relating to player development in match situations.

In elite soccer, performance tests are widely used to monitor the players and there are extensive data available on the physical performances of senior players (Dumbar and Power, 1997; Wisloff et al., 1998) and for some youth players (Hulse, 2010, unpublished; Le Gall et al., 2010; Reilly et al., 2000). The physical performances have been measured using both laboratory (Reilly et al., 2000; Wisloff et al., 1998) and field based tests (Dumbar and Power, 1997; Hulse, 2010, unpublished; Le Gall et al., 2010; Reilly et al., 2000; Wisloff et al., 1998). However, there are only limited studies which examined the validity of field tests as an indicator of match performance in elite youth (Castagna et al., 2009; Castagna et al., 2010) and professional adult soccer players. Also, these studies examined only a limited number of field tests (Castagna et al., 2009; Castagna et al., 2010; Krustrup et al., 2003; Rampinini et al., 2007a). Hence an examination of wide variety of field tests as valid indicators of match performance in youth and adult elite soccer players is essential as currently is it unknown how the data collected by clubs and coaches in field tests relates to match performance.

Therefore the main purpose of this thesis is to examine the physical characteristics, the development of the physical characteristics and the match demands of elite youth soccer players. Also, the relationship between the physical characteristics, maturity and match performance of players will be examined. Overall the thesis should contribute to enhanced methods of talent identification in young players and should add information to the limited body of literature which describes the development of the elite child and adolescent athletes during the pre-pubertal and pubescent period.

Chapter 2

Review of literature

2.1 Introduction

This review of literature discusses the physical characteristics, the physical performance and match running performance of elite senior and youth soccer players. The physical characteristics include standing height, body mass, sum of skinfolds and estimated body fat composition (section 2.2). The physical performance elements examined include sprint, agility, jump and endurance tests in both field and laboratory settings (section 2.2). In section 2.3, the match distances run at various speeds are examined in elite senior and youth soccer players and in section 2.4, the relationship between field test and match performance is examined. In the last section of the review, the influence of biological maturity on physical characteristics and physical performance of elite youth soccer players is examined (section 2.5)

2.2 Physical characteristics and physical performance of elite senior and youth soccer players

2.2.1 Physical characteristics and physical performances of elite senior soccer players

There has been a large amount of research conducted recently aiming to elucidate the physical characteristics and physical performances of elite *senior* soccer players (Clark et al., 2008; Cometti et al., 2001; Dunbar and Power, 1997; Edwards et al., 2003; Hulse, 2010, unpublished; Impellizzeri et al., 2006; Krustrup et al., 2003; Puga et al., 1993; Rampinini et al., 2007a; Rienzi et al., 2000; Wisloff et al., 2004; Zerguini et al., 2007). This research, has included measurements of: standing height, body mass, estimated body fat composition, sprint times over 5, 10, 20, 30 and 50 m, multiple sprint ability, agility, squat jump, counter movement jump without and with arms, leg muscle strength, estimated peak oxygen uptake, 'lactate threshold' using a laboratory treadmill running test and the Yo-Yo intermittent recovery test level 1 and 2 (Bangsbo et al., 2008).

The majority of the studies showed a mean chronological age in the mid twenties for elite professional soccer players from different countries (table 2.1-2.6). Mean standing height of elite senior soccer players was mostly in between 175-180 cm (table 2.1). The body mass of elite senior soccer players showed more variation compared to standing height. Mean body mass from the studies on elite senior soccer players from different countries was generally within the range of 70.0-80.0 kg (table 2.1). Mean estimated body fat composition of elite senior soccer players from different countries was around 10% in all of the studies (table 2.2). Only a few studies have examined the sprint performance of elite senior soccer players (Cometti et al., 2001; Kollah et al., 1993; Dumbar and Power, 1997; Tiryaki et al., 1997; Wisloff et al., 2004; Zerguini et al., 2007), but despite this lack of published studies on sprint performance, elite senior soccer players have been shown to sprint 5, 10, 20, 30 and 50 m in around 1.00, 1.80, 3.00, 4.00-4.30 and 6.80 s, respectively (table 2.3). The mean squat jump height of elite senior soccer players who compete in different countries in Europe was reported to be around 35 cm (table 2.4), the mean height of counter movement jump without arms for players who compete in the first and second division in France was around 40 cm (table 2.4) and the counter movement jump with arms for elite senior soccer players who compete in different countries ranged from 21-65 cm (table 2.4).

The Yo-Yo intermittent recovery tests and estimated peak oxygen uptake has been commonly employed in elite senior soccer players to profile their endurance ability. During the Yo-Yo intermittent recovery test level 1, the highest international players, moderate elite players and sub-elite players have been shown to cover 2190 m (N = 71), 2030 m (N = 89) and 1810 m (N = 29), respectively. During the Yo-Yo intermittent recovery test level 2, the players who were categorised in top elite, moderate elite and sub-elite covered 1260 m (N = 130), 1050 m (N = 130) and 840 m (N = 72), respectively (Bangsbo et al., 2008).

The method employed to directly measure peak oxygen uptake was laboratory test using treadmill and the method employed to estimate peak oxygen uptake were the Multi-stage fitness test (Ramsbottom et al., 1988) and 12 minutes run test (Cooper, 1978). Directly measured peak oxygen uptake of elite senior soccer players from different countries ranged from 52.7 to 67.6 $ml \cdot kg^{-1} \cdot min^{-1}$ and estimated peak oxygen uptake of elite senior soccer players from England and Turkey ranged from 51.1 to 60.7 $ml \cdot kg^{-1} \cdot min^{-1}$ (table 2.4). Peak oxygen uptake has been shown to differentiate successful and unsuccessful team in a league (Wisloff et al., 1998) and relate to the total amount of work done during a match (Hoff et al., 2002). Moreover, improvement in peak oxygen uptake lead to an increase in the total distance covered during a match (Helgerud et al., 2001). However, it is argued that peak oxygen uptake is not sensitive enough to reflect endurance fitness during a competitive season when changes in performance will be small and may indicate peripheral rather than central adaptations if it is assessed regularly (Svensson and Drust, 2005).

Table 2.1 Number of participants, chronological age, standing height, body mass, standard, country and authors from past studies on elite senior soccer players.

N	Chronological age (years)	Standing height (cm)	Body mass (kg)	Standard and country	Authors
18	25.6 ± 1.0	176.3 ± 1.2	75.7 ± 1.9	North American Soccer League	Raven et al., 1976
24	26.3 ± 4.2	173.4 ± 4.6	67.7 ± 5.0	Hong Kong first division	Ming-Kai et al., 1992
GK = 2	28	186	84.4	International, Portugal	Puga et al., 1993
CB = 3	29.3	185.3	75.9	International, Portugal	Puga et al., 1993
FB = 2	26.5	175	67.5	International, Portugal	Puga et al., 1993
MF = 8	28.4	176.8	74	International, Portugal	Puga et al., 1993
FW = 6	25.8	174.6	71.1	International, Portugal	Puga et al., 1993
18	22.5 ± 3.6		77.7 ± 7.6	Premier league, England	Dumbar and Power, 1997
14	25.8 ± 4.7		73.8 ± 5.8	Third division, England	Dumbar and Power, 1997
48	18-30 (range)	178.8 ± 3.8	74.8 ± 6.6	First division, Turkey	Tiryaki et al., 1997
48	18-30 (range)	177.7 ± 3.4	69.6 ± 4.1	Second division, Turkey	Tiryaki et al., 1997
48	18-30 (range)	178.8 ± 5.9	72.7 ± 6.5	Third division, Turkey	Tiryaki et al., 1997
14	Not stated	181.1 ± 4.8	76.9 ± 6.3	Winner of first division, Norway	Wisloff et al., 1998
15	Not stated	180.8 ± 4.9	76.8 ± 7.4	Bottom of first division, Norway	Wisloff et al., 1998
23	21.9 ± 3.6	175 ± 6	65.6 ± 6.1	Singaporean Internationals	Aziz et al., 2000
17	29 ± 4	177.0 ± 4.0	74.5 ± 4.4	South American Internationals	Rienzi et al., 2000

Table 2.1 (continued) Number of participants, chronological age, standing height, body mass, standard, country and authors from past studies on elite senior soccer players.

N	Chronological age (years)	Standing height (cm)	Body mass (kg)	Standard and country	Authors
23	25.2 ± 2.3	177.2 ± 5.9	73.1 ± 6.8	Saudi International players	Al-Hazzaa et al., 2001
29	26.1 ± 4.3	179.8 ± 4.4	74.5 ± 6.2	First division, France	Cometti et al., 2001
34	23.2 ± 5.6	178.0 ± 5.8	73.5 ± 14.7	Second division, France	Cometti et al., 2001
21	Not stated	178.8 ± 6.8	78.9 ± 6.0	New Zealand Internationals	Dowson et al., 2002
12	26.2 ± 3.3	177.0 ± 5.0	79.3 ± 9.4	Championship, England	Edwards et al., 2003
37	26: 22 - 32	181 (range: 169-194)	75.4 (range: 67.5-90.1)	Highest national leagues of respective countries	Krustrup et al., 2003
GK = 15+	23.5 ± 3.3	185.2 ± 4.7	81.4 ± 7.7	Two highest division, Iceland	Arnason et al., 2004
DF = 75+	24.2 ± 4.3	181.1 ± 5.4	76.9 ± 6.1	Two highest division, Iceland	Arnason et al., 2004
MF = 70+	24.7 ± 4.6	179.3 ± 5.2	75.9 ± 7.0	Two highest division, Iceland	Arnason et al., 2004
FW = 45+	23.1 ± 3.4	180.2 ± 5.3	75.3 ± 5.9	Two highest division, Iceland	Arnason et al., 2004
17	25.8 ± 2.9	177.3 ± 4.1	76.5 ± 7.6	UEFA Chmpions league, Norway	Wisloff et al., 2004
18	26.2 ± 4.5	181.9 ± 3.7	80.8 ± 7.8	Quarter final of UEFA champions league	Rampinini et al., 2007a
55	17-34 (range)	178.2 ± 6.1	72.6 ± 5.8	Professional, Algeria	Zerguini et al., 2007
42	25.0 ± 3.5	178.0 ± 3.0	79.4 ± 1.6	Championship, England	Clark et al., 2008

Table 2.2 Number of participants, chronological age, estimated body fat composition, standard, country and authors from past studies on elite senior soccer players.

N	Chronological age (years)	Estimated body fat composition (%)	Standard and country	Authors
18	25.6 ± 1.0	9.6 ± 0.7	North American Soccer League	Raven et al., 1976
24	26.3 ± 4.2	7.3 ± 3.0	Hong Kong first division	Ming-Kai et al., 1992
GK = 2	28	10.0	International, Portugal	Puga et al., 1993
CB = 3	29.3	10.1	International, Portugal	Puga et al., 1993
FB = 2	26.5	10.0	International, Portugal	Puga et al., 1993
MF = 8	28.4	11.4	International, Portugal	Puga et al., 1993
FW = 6	25.8	11.5	International, Portugal	Puga et al., 1993
18	22.5 ± 3.6	12.6 ± 2.9	Premier league, England	Dumbar and Power, 1997
14	25.8 ± 4.7	13.1 ± 2.6	Third division, England	Dumbar and Power, 1997
48	18-30 (range)	7.6 ± 0.7	First division, Turkey	Tiryaki et al., 1997
48	18-30 (range)	7.1 ± 0.4	Second division, Turkey	Tiryaki et al., 1997
48	18-30 (range)	7.2 ± 0.5	Third division, Turkey	Tiryaki et al., 1997

Table 2.2 (continued) Number of participants, chronological age, estimated body fat composition, standard, country and authors from past studies on elite senior soccer players.

N	Chronological age (years)	Estimated body fat composition (%)	Standard and country	Authors
17	29 ± 4	11.6 ± 3.3	South American Internationals	Rienzi et al., 2000
GK = 15+	23.5 ± 3.3	12.3 ± 5.3	Two highest division, Iceland	Arnason et al., 2004
DF = 75+	24.2 ± 4.3	10.6 ± 3.6	Two highest division, Iceland	Arnason et al., 2004
MF = 70+	24.7 ± 4.6	10.7 ± 4.2	Two highest division, Iceland	Arnason et al., 2004
FW = 45+	23.1 ± 3.4	9.6 ± 5.1	Two highest division, Iceland	Arnason et al., 2004
42	25.0 ± 3.5	12.6 ± 3.0	Championship, England	Clark et al., 2008

Table 2.3 Number of participants, chronological age, sprint performances, standard, country and authors from past studies on elite senior soccer players.

N	Chronological age (years)	Sprint (s)					Standard and country	Authors
		5 m	10 m	20 m	30 m	50 m		
20	Not stated	1.03 ± 0.08	1.79 ± 0.09	3.03 ± 0.11	4.19 ± 0.14		First division, Germany	Kollah et al., 1993
18	22.5 ± 3.6				3.94 ± 0.21		Premier league, England	Dumbar and Power, 1997
14	25.8 ± 4.7				4.15 ± 0.15		Third division, England	Dumbar and Power, 1997
48	18-30 (range)					6.8 ± 0.2	First division, Turkey	Tiryaki et al., 1997
48	18-30 (range)					6.9 ± 0.4	Second division, Turkey	Tiryaki et al., 1997
48	18-30 (range)					6.7 ± 0.2	Third division, Turkey	Tiryaki et al., 1997
29	26.1 ± 4.3		1.80 ± 0.06		4.22 ± 0.19		First division, France	Cometti et al., 2001
34	23.2 ± 5.6		1.82 ± 0.06		4.25 ± 0.15		Second division, France	Cometti et al., 2001
17	25.8 ± 2.9		1.82 ± 0.3	3.0 ± 0.3	4.0 ± 0.2		UEFA Chmpions league, Norway	Wisloff et al., 2004
55	17-34 (range)	1.02 ± 0.25	1.76 ± 0.26	3.09 ± 0.33			Professional, Algeria	Zerguini et al., 2007

Table 2.4 Number of participants, chronological age, standing vertical jump performances, standard, country and authors from past studies on elite senior soccer players.

N	Chronological age (years)	Squat jump (cm)	Counter movement jump without arms (cm)	Counter movement jump with arms (cm)	Standard and country	Authors
18	25.6 ± 1.0			20.8 ± 1	North American Soccer League	Raven et al., 1976
48	18-30 (range)			64.8 ± 4.6	First division, Turkey	Tiryaki et al., 1997
48	18-30 (range)			54.1 ± 5.7	Second division, Turkey	Tiryaki et al., 1997
48	18-30 (range)			57.0 ± 7.5	Third division, Turkey	Tiryaki et al., 1997
14	Not stated			56.7 ± 6.6	Winner of first division, Norway	Wisloff et al., 1998
15	Not stated			53.1 ± 4.0	Bottom of first division, Norway	Wisloff et al., 1998
29	26.1 ± 4.3	38.5 ± 3.8	41.6 ± 4.2		First division, France	Cometti et al., 2001
34	23.2 ± 5.6	33.9 ± 7.5	39.7 ± 5.2		Second division, France	Cometti et al., 2001
GK = 15+	23.5 ± 3.3	35.8 ± 5.3		38.0 ± 5.6	Two highest division, Iceland	Arnason et al., 2004
DF = 75+	24.2 ± 4.3	37.7 ± 4.9		39.3 ± 5.5	Two highest division, Iceland	Arnason et al., 2004
MF = 70+	24.7 ± 4.6	37.6 ± 4.8		39.3 ± 4.9	Two highest division, Iceland	Arnason et al., 2004
FW = 45+	23.1 ± 3.4	37.8 ± 4.4		39.4 ± 4.2	Two highest division, Iceland	Arnason et al., 2004
17	25.8 ± 2.9			56.4 ± 4.0	UEFA Chmpions league, Norway	Wisloff et al., 2004
18	26.2 ± 4.5	36.6 ± 3.8			Quarter final of UEFA champions league	Rampinini et al., 2007a
55	17-34 (range)			52.3 ± 5.27	Professional, Algeria	Zerguini et al., 2007

Table 2.5 Number of participants, chronological age, peak oxygen uptake, standard, country and authors from past studies on elite senior soccer players.

N	Chronological age (years)	Peak oxygen uptake ($ml \cdot kg^{-1} \cdot min^{-1}$)	Standard and country	Authors
18	25.6 ± 1.0	58.4 ± 0.8	North American Soccer League	Raven et al., 1976
GK = 2	28	52.7	International, Portugal	Puga et al., 1993
CB = 3	29.3	54.8	International, Portugal	Puga et al., 1993
FB = 2	26.5	62.1	International, Portugal	Puga et al., 1993
MF = 8	28.4	61.9	International, Portugal	Puga et al., 1993
FW = 6	25.8	60.6	International, Portugal	Puga et al., 1993
18	22.5 ± 3.6	60.7 ± 2.9	Premier league, England	Dumbar and Power, 1997
14	25.8 ± 4.7	58.8 ± 3.2	Third division, England	Dumbar and Power, 1997
48	18-30 (range)	51.6 ± 3.1	First division, Turkey	Tiryaki et al., 1997
48	18-30 (range)	51.1 ± 2.0	Second division, Turkey	Tiryaki et al., 1997
48	18-30 (range)	51.3 ± 2.1	Third division, Turkey	Tiryaki et al., 1997
14	Not stated	67.6 ± 4.0	Winner of first division, Norway	Wisloff et al., 1998
15	Not stated	59.9 ± 4.2	Bottom of first division, Norway	Wisloff et al., 1998

Dumbar and Power (1997) employed Multi-stage fitness test (Ramsbottom et al., 1988) and Tiryaki et al., (1997) used 12 min run test (Cooper, 1978). Rest of studies conducted laboratory test on a treadmill.

Table 2.5 (continued) Number of participants, chronological age, peak oxygen uptake, standard, country and authors from past studies on elite senior soccer players.

N	Chronological age (years)	Peak oxygen uptake ($ml \cdot kg^{-1} \cdot min^{-1}$)	Standard and country	Authors
23	21.9 ± 3.6	58.2 ± 3.7	Singaporean Internationals	Aziz et al., 2000
12	26.2 ± 3.3	63.3 ± 5.8	Championship, England	Edwards et al., 2003
GK = 15+	23.5 ± 3.3	57.3 ± 4.7	Two highest division, Iceland	Arnason et al., 2004
DF = 75+	24.2 ± 4.3	62.8 ± 4.4	Two highest division, Iceland	Arnason et al., 2004
MF = 70+	24.7 ± 4.6	63.0 ± 4.3	Two highest division, Iceland	Arnason et al., 2004
FW = 45+	23.1 ± 3.4	62.9 ± 5.5	Two highest division, Iceland	Arnason et al., 2004
17	25.8 ± 2.9	65.7 ± 4.3	UEFA Chmpions league, Norway	Wisloff et al., 2004
42	25.0 ± 3.5	61.6 ± 0.6	Championship, England	Clark et al., 2008

All studies employed laboratory test on a treadmill.

2.2.2 Physical characteristics and physical performances of elite youth soccer players

Fitness testing has also been conducted on elite youth soccer players to provide their profile of physical characteristics. In elite youth soccer players, a result from fitness testing and anthropometric measurement can also be used for investigation of strengths and weaknesses of the players, as well as identification or discrimination of talent (Reilly et al., 2000).

There were number of tests used to measure fitness components and anthropometry, and these were assessed using both laboratory based tests and field tests. The anthropometric measurements included: standing height; body mass; body fat; girth. The fitness components which have been measured in research involved sprint speed, agility, repeated sprint ability, endurance, power, strength and flexibility (Table 2.6-2.11).

Standing height and body mass

Standing height and body mass of elite youth soccer players from different countries were reported (Table 2.6). Both standing height and body mass gradually increased with chronological age from 9 to 18. Mean standing height of elite youth soccer players ranged from 135.2 cm for 9.2 years old (Hulse, 2010, unpublished) to 181.3 cm for 18.1 years old (Helgerud et al., 2001) and mean body mass of elite youth soccer players progressively increased with chronological age from 30.8 kg for 9.2 years old (Hulse, 2010, unpublished) to 73.0 kg for 18.1 years old (Helgerud et al., 2001).

Body fat composition

Mean body fat composition of elite youth soccer players from different countries ranged from 11.0 to 13.0% and no tendency of increase or decrease in body fat composition with chronological age was observed. However, chronological age range of the players who were included in research was 13.4 to 16.4 years. Therefore there is a lack of data regarding body fat composition of elite youth soccer players outside of the age range of 13.4 to 16.4 years (table 2.7).

Sprint

There were several distances used to measure sprint speed of youth elite soccer players (table 2.8) and which were 5, 10, 15, 20, 25, 30 and 40 m (Reilly et al., 2000; Franks et al., 2002;

Chamari et al., 2004; McMillan et al., 2005a; McMillan et al., 2005b; Hulse, 2010, unpublished). The sprint distances most commonly employed were 10, 20 and 30 m and the players gradually became faster to cover the distances with chronological age. Mean sprint time to cover 10, 20 and 30 m ranged from 2.04 s (U9: Hulse, 2010, unpublished) to 1.70 s (U18: Hulse, 2010, unpublished), 3.70 s (U9: Hulse, 2010, unpublished) to 2.97 s (U18: Hulse, 2010, unpublished) and 4.3 s (U13: Vaeyens et al., 2006) to 4.48 s (U16: Reilly et al., 2000), respectively. However, most of the studies employed only one or two sprint distances and the participants recruited were mostly 13 years and older elite youth soccer players. Hence, there is a lack of information on sprinting ability over different distances from the same group of participants as match play of soccer involves different sprint distances (Bradley et al., 2009; Di Salvo et al., 2007; Mohr et al., 2003). Moreover, further investigation of sprinting ability in 12 years and younger elite soccer players is required.

Agility

There were a few different tests employed to assess agility of elite youth soccer players. The agility tests used were: four line sprint (Rosch et al., 2000); three corner run (Rosch et al., 2000); 40m sprint with turns (Reilly et al., 2000); Shuttle run 5.5 m x 4 (Graganta et al., 1993); Slalom agility test (Hulse, 2010, unpublished). Although there have been different agility tests introduced in the previous studies, none of the studies compared the agility tests to investigate a most suitable test to profile agility of elite youth soccer players. Moreover, as different agility tests were employed in most of studies, it is not possible to compare agility test scores to examine a development of agility in elite youth soccer players over different age groups. There is only one study investigated agility of elite youth soccer players over several age groups from Premier League Academy and the study employed Slalom agility test (Hulse, 2010, unpublished) to assess the players. The mean completion time of Slalom agility test gradually declined with chronological age and it ranged from 5.04 s for 9 years old to 4.07 s for 17 years old (table 2.9). However, this study only used Slalom agility test that suitability of other agility tests on elite youth soccer players needs to be investigated (Svensson and Drust, 2005).

Standing vertical jumps

Squat jump, counter movement jump without and with arms have commonly been employed to create a part of physical profile of elite youth soccer players (table 2.10). This is possibly because the standing vertical jumps are relatively good predictors of leg strength (Wisloff et al., 2004) and, mixed use of standing vertical jumps may allow a discrimination of concentric muscle action of the leg extensors and the effect of pre-stretch (Markovic et al., 2004). Score from three standing vertical jumps has increased with chronological age and jump height from squat jump, counter movement jump without arms and counter movement with arms ranged from 24.5 cm (U9: Hulse, 2010, unpublished) to 51.3 cm (U17: Chamari et al., 2004), 24.6 cm (U9: Hulse, 2010, unpublished) to 53.4 cm (U17: McMillan et al., 2005b)) and 27.9 cm (U9: Hulse, 2010, unpublished) to 67.7 cm (U18: Taiana et al., 1993), respectively.

Endurance

Estimated peak oxygen uptake has been widely assessed in many studies to profile physical characteristics of elite youth soccer players (table 2.11). Methods commonly employed to examine estimated peak oxygen uptake were the Multi-stage fitness test (Ramsbottom et al., 1988), continuous progressive track run test (Chtara et al., 2005) and laboratory based test on treadmill. There was an increase in estimated peak oxygen uptake in elite youth soccer players with chronological age from 41.2 $ml \cdot kg^{-1} \cdot min^{-1}$ for the U9 age group (Hulse, 2010, unpublished) to 69.8 $ml \cdot kg^{-1} \cdot min^{-1}$ for the U17 age group (McMillan et al., 2005b). However, estimated peak oxygen uptake may not be sensitive enough to reflect important aspects in performance of match play (Bangsbo and Lindqvist, 1992). The Yo-Yo intermittent recovery test is suggested to be a more valid indicator of soccer specific aerobic fitness and activity patterns during a match than direct assessment or field predictions of peak oxygen uptake (Svensson and Drust, 2005). Therefore, the Yo-Yo intermittent recovery test should be conducted to measure endurance fitness of elite youth soccer players instead of examining estimated peak oxygen uptake or both assessments should be conducted in parallel.

The 14 years old elite soccer players from San Marino Youth Academy participated in the Yo-Yo intermittent recovery test (level 1) and they covered 842 (± 352) m during the test (Castagna et al., 2009). This is the only study conducted the Yo-Yo intermittent recovery test on elite youth soccer players from the author’s knowledge. Therefore, there is a need to examine performance of elite youth soccer players on the Yo-Yo intermittent recovery test to profile soccer specific endurance ability of elite youth soccer players.

Table 2.6 Number of participants, chronological age, standing height, body mass, standard, country and authors from past studies on elite youth soccer players.

N	Chronological age (years)	Standing height (cm)	Body mass (kg)	Standard and country	Authors
183	9.2 ± 0.4	135.2 ± 5.4	30.8 ± 3.7	Premier League Academy, England	Hulse, 2010, unpublished
206	10.2 ± 0.3	140.2 ± 5.6	34.1 ± 4.3	Premier League Academy, England	Hulse, 2010, unpublished
236	11.2 ± 0.3	145.3 ± 6.8	37.6 ± 5.4	Premier League Academy, England	Hulse, 2010, unpublished
269	12.2 ± 0.3	151.6 ± 7.5	42.0 ± 6.5	Premier League Academy, England	Hulse, 2010, unpublished
9	12.6 ± 0.6	154.1 ± 8.2	42.5 ± 7.2	Elite, Denmark	Stroyer et al., 2004
248	13.2 ± 0.3	157.6 ± 8.7	46.9 ± 8.1	Premier League Academy, England	Hulse, 2010, unpublished
20	13.3 ± 0.3	162 ± 6	52.9 ± 5.2	Youth team of Professional club in Division 1, Brazil	Dezan et al., 2004
60	13.6 ± 0.2	162 ± 8	53.4 ± 9.7	Youth team of professional club in second division, Portugal	Capela et al., 2004a
16	13.4 ± 0.4	165.2 ± 10.5	52.5 ± 9.9	Elite, France (became international player)	Le Gall et al., 2010
56	13.6 ± 0.4	165.0 ± 8.8	53.8 ± 9.5	Elite, France (became professional player)	Le Gall et al., 2010
32	13.0- 13.9 (range)	157.7 ± 8.4	44.3 ± 6.5	First (highest) and second division, Belgium	Vaeyens et al., 2006

Table 2.6 (continued) Number of participants, chronological age, standing height, body mass, standard, country and authors from past studies on elite youth soccer players.

N	Chronological age (years)	Standing height (cm)	Body mass (kg)	Standard and country	Authors
7	14.0 ± 0.2	172.2 ± 6.1	57.5 ± 7.2	Elite, Denmark	Stroyer et al., 2004
288	14.2 ± 0.3	166.6 ± 8.4	55.5 ± 9.2	Premier League Academy, England	Hulse, 2010, unpublished
16	14.4 ± 0.4	171.5 ± 9.4	59.3 ± 10.3	Elite, France (became international player)	Le Gall et al., 2010
54	14.5 ± 0.4	170.8 ± 8.0	60.3 ± 9.2	Elite, France (became professional player)	Le Gall et al., 2010
60	14.6 ± 0.2	169 ± 10	59.1 ± 10.7	Youth team of professional club in second division, Portugal	Capela et al., 2004a
29	14.8 ± 0.3	172 ± 7	57.4 ± 8.7	The highest league, Czech	Psotta and Bunc, 2004
37	14.0-14.9 (range)	167.5 ± 8.8	53.4 ± 9.6	First (highest) and second division, Belgium	Vaeyens et al., 2006
35	15.0-15.9 (range)	171.7 ± 7.4	57.9 ± 8.2	First (highest) and second division, Belgium	Vaeyens et al., 2006
252	15.2 ± 0.4	171.9 ± 8.0	62.2 ± 9.3	Premier League Academy, England	Hulse, 2010, unpublished
60	15.5 ± 0.2	175 ± 6	67.3 ± 4.7	Youth team of professional club in second division, Portugal	Capela et al., 2004a
16	15.4 ± 0.4	176.1 ± 7.5	65.3 ± 8.8	Elite, France (became international player)	Le Gall et al., 2010
57	15.4 ± 0.4	175.3 ± 8.2	66.0 ± 8.2	Elite, France (became professional player)	Le Gall et al., 2010

Table 2.6 (continued) Number of participants, chronological age, standing height, body mass, standard, country and authors from past studies on elite youth soccer players.

N	Chronological age (years)	Standing height (cm)	Body mass (kg)	Standard and country	Authors
25	16.0 ± 0.5	176 ± 7	68.6 ± 7.8	International, Nigeria	Chibane et al., 2004
47	16.0 ± 0.5	175.7 ± 5.2	66.2 ± 5.6	Prospective international players, Croatia	Jankovic et al., 1993
16	16.1 ± 0.7	177.6 ± 7.3	71.3 ± 6.7	Australian institute of sport, Australia	Tumilty, 1993
194	16.1 ± 0.4	175.9 ± 6.0	67.2 ± 7.8	Premier League Academy, England	Hulse, 2010, unpublished
11	16.9 ± 0.4	177.0 ± 6.4	70.6 ± 8.1	Celtic FC (Scottish premier league) U17s, Scotland	McMillan et al., 2005b
29	17.2 ± 0.8	178.1 ± 5.8	69.1 ± 4.7	Championship includes junior team of Serie C, Italy	Impellizzeri et al., 2006
136	17.2 ± 0.4	178.0 ± 6.7	70.7 ± 7.9	Premier League Academy, England	Hulse, 2010, unpublished
23	17.4 ± 0.5	179 ± 4	70.4 ± 5.2	Youth team of Pro Patria (Serie C), Italy	Rampinini et al., 2004
34	17.5 ± 1.1	177.8 ± 6.7	70.5 ± 6.4	Elite, Tunisia	Chamari et al., 2004
9	17.8 ± 0.2	177.7 ± 1.1	71.3 ± 3.2	Professionals at Celtic FC, Scotland	McMillan et al., 2005a
19	18.1 ± 0.8	181.3 ± 5.6	72.2 ± 11.1	Most successful 2 teams in last 5 years, Norway	Helgerud et al., 2001
162	18.1 ± 0.4	179.0 ± 5.7	73.0 ± 7.0	Premier League Academy, England	Hulse, 2010, unpublished

Table 2.7 Number of participants, chronological age, estimated body fat composition, standard, country and authors from past studies on elite youth soccer players.

N	Chronological age (years)	Estimated body fat composition (%)	Standard and country	Authors
16	13.4 ± 0.4	11.9 ± 1.4	Elite, France (became international player)	Le Gall et al., 2010
56	13.6 ± 0.4	12.5 ± 2.6	Elite, France (became professional player)	Le Gall et al., 2010
18	14.0 ± 0.4	11.8 ± 3.2	Elite, Tunisia	Chamari et al., 2005
16	14.4 ± 0.4	11.6 ± 1.8	Elite, France (became international player)	Le Gall et al., 2010
54	14.5 ± 0.4	13.0 ± 5.0	Elite, France (became professional player)	Le Gall et al., 2010
16	15.4 ± 0.4	11.3 ± 1.5	Elite, France (became international player)	Le Gall et al., 2010
57	15.4 ± 0.4	12.6 ± 2.3	Elite, France (became professional player)	Le Gall et al., 2010
16	16.4 (range: 16.2-16.6)	11.3 ± 2.1	International players belonged to an English club	Reilly et al., 2000

Table 2.8 Number of participants, chronological age, 5, 10, 15, 20 and 30 m sprint times, standard, country and authors from past studies on elite youth soccer players.

N	Chronological age (years)	Sprint (s)					Standard and country	Authors
		5 m	10 m	15 m	20 m	30 m		
183	9.2 ± 0.4		2.04 ± 0.11		3.70 ± 0.17		Premier League Academy, England	Hulse, 2010, unpublished
206	10.2 ± 0.3		2.00 ± 0.09		3.60 ± 0.17		Premier League Academy, England	Hulse, 2010, unpublished
236	11.2 ± 0.3		1.95 ± 0.09		3.51 ± 0.16		Premier League Academy, England	Hulse, 2010, unpublished
42	12. 0-12.9 (range)					4.4 ± 0.2	First (highest) and second division, Belgium	Vaeyens et al., 2006
269	12.2 ± 0.3		1.94 ± 0.09		3.46 ± 0.17		Premier League Academy, England	Hulse, 2010, unpublished
32	13.0-13.9					4.3 ± 0.2	First (highest) and second division, Belgium	Vaeyens et al., 2006
248	13.2 ± 0.3		1.87 ± 0.09		3.33 ± 0.17		Premier League Academy, England	Hulse, 2010, unpublished
16	13.4 ± 0.4		1.96 ± 0.10		3.34 ± 0.14		Elite, France (became international player)	Le Gall et al., 2010
56	13.6 ± 0.4		1.95 ± 0.09		3.32 ± 0.14		Elite, France (became professional player)	Le Gall et al., 2010

Table 2.8 (continued) Number of participants, chronological age, 5, 10, 15, 20 and 30 m sprint times, standard, country and authors from past studies on elite youth soccer players.

N	Chronological age (years)	Sprint (s)					Standard and country	Authors
		5 m	10 m	15 m	20 m	30 m		
37	14.0-14.9 (range)					4.1 ± 0.2	First (highest) and second division, Belgium	Vaeyens et al., 2006
288	14.2 ± 0.3		1.82 ± 0.10		3.21 ± 0.18		Premier League Academy, England	Hulse, 2010, unpublished
16	14.4 ± 0.4		1.87 ± 0.08		3.17 ± 0.13		Elite, France (became international player)	Le Gall et al., 2010
54	14.5 ± 0.4		1.89 ± 0.08		3.20 ± 0.14		Elite, France (became professional player)	Le Gall et al., 2010
31	15.0-15.9 (range)					3.9 ± 0.2	First (highest) and second division, Belgium	Vaeyens et al., 2006
252	15.2 ± 0.4		1.76 ± 0.09		3.09 ± 0.17		Premier League Academy, England	Hulse, 2010, unpublished
16	15.4 ± 0.4		1.82 ± 1.10		3.06 ± 0.16		Elite, France (became international player)	Le Gall et al., 2010
57	15.4 ± 0.4		1.85 ± 0.08		3.12 ± 0.12		Elite, France (became professional player)	Le Gall et al., 2010

Table 2.8 (continued) Number of participants, chronological age, 5, 10, 15, 20 and 30 m sprint times, standard, country and authors from past studies on elite youth soccer players.

N	Chronological age (years)	Sprint (s)					Standard and country	Authors
		5 m	10 m	15 m	20 m	30 m		
16	16.1 ± 0.7				3.02 ± 0.11		Australian institute of sport, Australia	Tumilty, 1993
194	16.1 ± 0.4		1.73 ± 0.09		3.02 ± 0.14		Premier League Academy, England	Hulse, 2010, unpublished
16	16.4 (range: 16.2-16.6)	1.04 ± 0.03		2.44 ± 0.07		4.31 ± 0.14	International players belonged to an English club	Reilly et al., 2000
11	16.9 ± 0.4		1.96 ± 0.06				Celtic FC (Scottish premier league) U17, Scotland	McMillan et al., 2005b
136	17.2 ± 0.4		1.71 ± 0.09		2.97 ± 0.13		Premier League Academy, England	Hulse, 2010, unpublished
34	17.5 ± 1.1		1.87 ± 0.10			4.38 ± 0.18	Elite, Tunisia	Chamari et al., 2004
15	18.1 ± 0.3		1.99 ± 0.36			4.48 ± 0.15	Fourth division players at Institute national du Football de Clairefontaine, France	Taiana et al., 1993
19	18.1 ± 0.8		1.87 ± 0.05				Most successful 2 teams in last 5 years, Norway	Helgerud et al., 2001
162	18.2 ± 0.4		1.70 ± 0.08		2.97 ± 0.11		Premier League Academy, England	Hulse, 2010, unpublished

Table 2.9 Number of participants, chronological age, scores from Slalom agility test, standard, country and authors from past studies on elite youth soccer players.

N	Chronological age (years)	Slalom agility test (s)	Standard and country	Authors
183	9.2 ± 0.4	5.04 ± 0.30	Premier League Academy, England	Hulse, 2010, unpublished
206	10.2 ± 0.3	4.88 ± 0.30	Premier League Academy, England	Hulse, 2010, unpublished
236	11.2 ± 0.3	4.70 ± 0.29	Premier League Academy, England	Hulse, 2010, unpublished
269	12.2 ± 0.3	4.68 ± 0.31	Premier League Academy, England	Hulse, 2010, unpublished
248	13.2 ± 0.3	4.55 ± 0.27	Premier League Academy, England	Hulse, 2010, unpublished
288	14.2 ± 0.3	4.44 ± 0.31	Premier League Academy, England	Hulse, 2010, unpublished
252	15.2 ± 0.4	4.26 ± 0.28	Premier League Academy, England	Hulse, 2010, unpublished
194	16.1 ± 0.4	4.17 ± 0.27	Premier League Academy, England	Hulse, 2010, unpublished
136	17.2 ± 0.4	4.07 ± 0.26	Premier League Academy, England	Hulse, 2010, unpublished
162	18.1 ± 0.4	4.11 ± 0.25	Premier League Academy, England	Hulse, 2010, unpublished

Table 2.10 Number of participants, chronological age, scores from squat jump, counter movement jump without and with arms, standard, country and authors from past studies on elite youth soccer players.

N	Chronological age (years)	Squat jump (cm)	Counter movement jump without arms (cm)	Counter movement jump with arms (cm)	Standard and country	Authors
183	9.2 ± 0.4	24.5 ± 3.8	24.6 ± 3.9	27.9 ± 4.4	Premier League Academy, England	Hulse, 2010, unpublished
206	10.2 ± 0.3	26.2 ± 4.0	26.2 ± 4.3	29.6 ± 4.7	Premier League Academy, England	Hulse, 2010, unpublished
236	11.2 ± 0.3	27.8 ± 4.0	28.3 ± 4.0	32.2 ± 4.4	Premier League Academy, England	Hulse, 2010, unpublished
47	12.0-12.9 (range)			33.7 ± 4.7	First (highest) and second division, Belgium	Vaeyens et al., 2006
269	12.2 ± 0.3	28.5 ± 4.3	28.8 ± 4.3	32.5 ± 4.9	Premier League Academy, England	Hulse, 2010, unpublished
34	13.0-13.9 (range)			37.1 ± 5.4	First (highest) and second division, Belgium	Vaeyens et al., 2006
248	13.2 ± 0.3	31.1 ± 4.3	31.5 ± 4.6	35.9 ± 5.1	Premier League Academy, England	Hulse, 2010, unpublished
16	13.4 ± 0.4			43.7 ± 7.3	Elite, France (became international player)	Le Gall et al., 2010
56	13.6 ± 0.4			42.6 ± 5.8	Elite, France (became professional player)	Le Gall et al., 2010

Table 2.10 (continued) Number of participants, chronological age, scores from squat jump, counter movement jump without and with arms, standard, country and authors from past studies on elite youth soccer players.

N	Chronological age (years)	Squat jump (cm)	Counter movement jump without arms (cm)	Counter movement jump with arms (cm)	Standard and country	Authors
37	14.0-14.9 (range)			40.1 ± 4.5	First (highest) and second division, Belgium	Vaeyens et al., 2006
288	14.2 ± 0.3	33.9 ± 5.0	34.5 ± 5.1	38.9 ± 5.8	Premier League Academy, England	Hulse, 2010, unpublished
16	14.4 ± 0.4			47.9 ± 6.1	Elite, France (became international player)	Le Gall et al., 2010
54	14.5 ± 0.4			46.3 ± 5.5	Elite, France (became professional player)	Le Gall et al., 2010
35	15.0-15.9 (range)			44.7 ± 5.0	First (highest) and second division, Belgium	Vaeyens et al., 2006
252	15.2 ± 0.4	36.0 ± 4.7	37.0 ± 5.0	42.3 ± 5.5	Premier League Academy, England	Hulse, 2010, unpublished
16	15.4 ± 0.4			50.6 ± 6.4	Elite, France (became international player)	Le Gall et al., 2010
57	15.4 ± 0.4			49.4 ± 5.7	Elite, France (became professional player)	Le Gall et al., 2010
194	16.1 ± 0.4	37.7 ± 5.0	38.7 ± 5.2	44.5 ± 5.7	Premier League Academy, England	Hulse, 2010, unpublished
16	16.4 (range: 16.2-16.6)			55.8 ± 5.8	International players belonged to an English club	Reilly et al., 2000

Table 2.10 (continued) Number of participants, chronological age, scores from squat jump, counter movement jump without and with arms, standard, country and authors from past studies on elite youth soccer players.

N	Chronological age (years)	Squat jump (cm)	Counter movement jump without arms (cm)	Counter movement jump with arms (cm)	Standard and country	Authors
11	16.9 ± 0.4	40.3 ± 6.1	53.4 ± 4.2		Celtic FC (Scottish premier league) U17, Scotland	McMillan et al., 2005b
136	17.2 ± 0.4	39.0 ± 5.1	39.5 ± 5.5	45.6 ± 6.2	Premier League Academy, England	Hulse, 2010, unpublished
34	17.5 ± 1.1	51.3 ± 6.7			Elite, Tunisia	Chamari et al., 2004
15	18.1 ± 0.3	45.3 ± 2.1	50.3 ± 4.1	67.7 ± 3.4	Fourth division players at Institute national du Football de Clairefontaine, France	Taiana et al., 1993
19	18.1 ± 0.8			54.7 ± 3.8	Most successful 2 teams in last 5 years, Norway	Helgerud et al., 2001
162	18.2 ± 0.4	39.1 ± 4.5	40.1 ± 4.7	46.2 ± 5.3	Premier League Academy, England	Hulse, 2010, unpublished

Table 2.11 Number of participants, chronological age, estimated peak oxygen uptake, standard, country and authors from past studies on elite youth soccer players.

N	Chronological age (years)	VO_2peak ($ml \cdot kg^{-1} \cdot min^{-1}$)	Standard and country	Authors
63	9.2 ± 0.3	41.2 ± 4.9	Premier League Academy, England	Hulse, 2010, unpublished
80	10.2 ± 0.3	43.6 ± 4.4	Premier League Academy, England	Hulse, 2010, unpublished
81	11.2 ± 0.3	45.3 ± 4.4	Premier League Academy, England	Hulse, 2010, unpublished
104	12.2 ± 0.3	47.8 ± 4.4	Premier League Academy, England	Hulse, 2010, unpublished
9	12.6 ± 0.6	58.6 ± 5.0	Elite, Denmark	Stroyer et al., 2004
83	13.2 ± 0.4	50.2 ± 4.2	Premier League Academy, England	Hulse, 2010, unpublished
16	13.4 ± 0.4	59.2 ± 3.2	Elite, France (became international player)	Le Gall et al., 2010
56	13.6 ± 0.4	58.2 ± 2.69	Elite, France (became professional player)	Le Gall et al., 2010

Hulse (2010, unpublished) employed the Multi-stage fitness test (Ramsbottom et al., 1988). Le Gall et al. (2010) employed continuous progressive track run test (Chtara et al., 2005). Rest of the studies employed laboratory test on treadmill.

Table 2.11 (continued) Number of participants, chronological age, estimated peak oxygen uptake, standard, country and authors from past studies on elite youth soccer players.

N	Chronological age (years)	VO_2peak (ml·kg^{-1}·min^{-1})	Standard and country	Authors
7	14.0 ± 0.2	63.7 ± 8.5	Elite, Denmark	Stroyer et al., 2004
18	14.0 ± 0.4	70.7 ± 4.3	Elite, Tunisia	Chamari et al., 2005
94	14.2 ± 0.3	52.5 ± 3.9	Premier League Academy, England	Hulse, 2010, unpublished
16	14.4 ± 0.4	61.5 ± 59.9	Elite, France (became international player)	Le Gall et al., 2010
54	14.5 ± 0.4	59.9 ± 2.7	Elite, France (became professional player)	Le Gall et al., 2010
73	15.2 ± 0.4	54.2 ± 3.3	Premier League Academy, England	Hulse, 2010, unpublished
16	15.4 ± 0.4	62.4 ± 2.7	Elite, France (became international player)	Le Gall et al., 2010
57	15.4 ± 0.4	62.2 ± 2.7	Elite, France (became professional player)	Le Gall et al., 2010
47	16.0 ± 0.5	59.9 ± 6.3	Prospective international players, Croatia	Jankovic et al., 1993
16	16.1 ± 0.7	61.4 ± 4.0	Australian institute of sport, Australia	Tumilty, 1993
64	16.1 ± 0.3	57.4 ± 4.0	Premier League Academy, England	Hulse, 2010, unpublished
16	16.4 (range: 16.2-16.6)	59.0 ± 1.7	International players belonged to an English club	Reilly et al., 2000

Hulse (2010) and Reilly et al. (2000) employed the Multi-stage fitness test. Le Gall et al. (2008) employed continuous progressive track run test. Rest of the studies employed laboratory test on treadmill.

Table 2.11 (continued) Number of participants, chronological age, estimated peak oxygen uptake, standard, country and authors from past studies on elite youth soccer players.

N	Chronological age (years)	VO_2peak ($ml \cdot kg^{-1} \cdot min^{-1}$)	Standard and country	Authors
11	16.9 ± 0.4	69.8 ± 6.6	Celtic FC (Scottish premier league) U17, Scotland	McMillan et al., 2005b
41	17.1 ± 0.3	59.0 ± 3.6	Premier League Academy, England	Hulse, 2010, unpublished
29	17.2 ± 0.8	61.0 ± 4.1	Championship includes junior team of Serie C, Italy	Impellizzeri et al., 2006
34	17.5 ± 1.1	61.1 ± 4.6	Elite, Tunisia	Chamari et al., 2004
19	18.1 ± 0.8	64.3 ± 3.9	Most successful 2 teams in last 5 years, Norway	Helgerud et al., 2001
36	18.1 ± 0.3	59.1 ± 4.2	Premier League Academy, England	Hulse, 2010, unpublished

Hulse (2010) employed the Multi-stage fitness test (Ramsbottom et al., 1988). Rest of the studies employed laboratory test on treadmill.

2.3 Match distance and speeds for elite senior and elite youth soccer players

2.3.1 Match analysis methods in soccer

In soccer, there has been a large amount of match analysis conducted on both male and female adults from amateur to elite professional players (Carling et al., 2008). There have been a variety of methods used to analyse distance covered by the players and these methods have been used to monitor just one player at once or several players simultaneously (Carling et al., 2008). From the late 1900s, video analysis was used commonly (Bangsbo, 1991; Mayhew and Wenger, 1985; Mohr et al., 2003; Reilly and Thomas, 1976; Rienzi et al., 2000; Withers et al., 1982) and one such method involved positioning video cameras near the side of the pitch, at the level of the halfway line, at a height of approximately 15 m and at a distance of 30-40 m from the touchline to film all players in the team. In addition players were videotaped on a separate occasions for reference purposes whilst performing specific activities (from walking to sprinting) in order to provide calibration values (Bangsbo, 1991; Mohr et al., 2003).

As technology advanced, the analysis began to incorporate electronic devices and mathematical modelling. The triangular survey method uses two cameras per player and calculates the position of the player using the length of the base-line and two angles. The base of the triangle is constituted by the distance between the two observation points, which are two sets of movable cameras on a tripod. Angles necessary for calculations are obtained by an encoder mounted at the base of each camera tracking down the movement of cameras in relation to the base. Angular signals obtained by the encoders are sequentially converted into digital data and recorded for post-match analysis. Video-based multi-player tracking systems such as Pro Zone (Leeds, England) generally require the permanent installation of several cameras fixed in optimally calculated positions to cover the entire surface of play. The stadium pitch is calibrated in terms of height, length and width and transformed into a two-dimensional model to allow player positions to be calculated (Di Salvo et al., 2006).

An alternative to video analysis suitable for locations where multiple cameras cannot easily used is the Global Positioning System (GPS) which was first used in 2007 in soccer (Hewitt et al., 2007). This system requires each player to wear a receiver, which draws on signals sent from at least three earth orbiting satellites to determine positional information. There are several different GPS receivers available produced by different manufacturers and devices with different signal frequencies are also available. Popularly studied GPS devices in field sports are SPI-10 (1 Hz, GPSport, Australia), SPI elite (1 Hz, GPSport, Australia), WiSPI elite (1 Hz, GPSport, Australia), SPI pro (5 Hz, GPSport, Australia) and MinimaxX (1 Hz and 5 Hz, Catapult Innovations, Scoresby, Australia). The validity and reliability of the 1 Hz, SPI elite (GPSport, Australia) was assessed using a circuit (487 m). Male and female adult games players (N = 9) completed 14 laps in a trial and the circuit involved moving at different speeds including walking to sprinting and various agility runs (8.5-52.3 m). The actual distance covered by the participants in the trial (6818.0 m) and the total distance measured by the devices only differed by 2.5 m and there was less than a 1% difference in the actual distance covered and the distance measured by the devices during agility runs. The mean speed during different agility runs ranged from 1.5 to 3.6 $m \cdot s^{-1}$ (MacLeod et al., 2009). These findings have been confirmed by several other studies which employed SPI-10 (1 Hz, GPSport, Australia: Jennings et al., 2010; Coutts and Duffield, 2010), SPI elite (1 Hz, GPSport, Australia: Coutts and Duffield, 2010), WiSPI elite (1 Hz, GPSport, Australia: Gray et al., 2010; Coutts and Duffield, 2010) and MinimaxX (1 Hz, Catapult Innovations, Australia: Jennings et al., 2010). In contrast, Duffield and colleagues (2010) reported that compared to 22 camera VICON motion analysis system (100Hz, Oxford Metrics, UK), 1 Hz GPS (1 Hz, SPI elite, GPSport, Australia) can underestimate the distance by up to around 40% if a movement is repeated (over 4 m and 8 m) in confined spaces (mean speed = 0.8-1.4 $m \cdot s^{-1}$, peak speed = 1.9-2.7 $m \cdot s^{-1}$). However, it is questionable whether the video system utilised was a suitable gold standard to compare the 1 Hz system against and no actual measurements of distances were made. Thus, overall, these studies showed that the 1 Hz GPS has acceptable validity (MacLeod et al., 2009; Gray et al. 2010) up to speeds of 3.6 $m \cdot s^{-1}$ except possibly where movements are repeated in very confined areas (Duffield, 2010). However, it is encouraging that the MacLeod study (MacLeod et al. 2009) attempted to replicate the movement patterns observed in field hockey, which has a similar movement pattern to soccer, and found very acceptable validity at the speeds and patterns of movement tested.

At higher speeds, however, above 4 $m \cdot s^{-1}$ which do occur in soccer, some poor validity has been observed in earlier studies. One study which included some fast speeds (1 Hz, WiSPI elite, GPSport, Australia) found that GPS overestimated the distance covered by 3% when participants walked (~1.6 m·s^{-1}), jogged (~3.5 m·s^{-1}), ran (5 m·s^{-1}) and sprinted (7-8 m·s^{-1}) on a linear 200 m course. However, only two participants completed this study and the data collection was undertaken in Australia where the satellite coverage is known to be worse than in the UK and other areas of Europe (Gray et al., 2010). When University physical education students sprinted over 15 and 30 m in a straight line, the correlation between peak speed assessed by GPS (1 Hz, SPI elite, GPSport, Australia) and sprint time over 15 m (r = 0.87) was lower than that between GPS peak speed assessment and sprint time over 30 m (r = 0.94) (Barvero-Alvarez et al., 2010). In another study, GPS (1 Hz, MinimaxX, Catapult Innovations, Australia) showed a larger error (30.9% vs. 1.9%) in an estimation of short sprint distance in the first 20 m (0-20 m) than the second 20 m (20-40 m) when elite senior Australian footballers sprinted 40 m due to a higher acceleration in the earlier phase (Jennings et al., 2010). Moreover, GPS (1 Hz, MinimaxX, Catapult Innovations, Australia) underestimated a distance by 12-22% when elite senior Australian footballers strode or sprinted through a 10 m x 4 zig-zag course with three 90º change of directions and 5 m x 8 zig-zag course with seven 90º change of directions (Jennings et al., 2010). Furthermore, in a 200 m course with circular change of directions, a GPS (1 Hz, WiSPI elite, GPSport, Australia) underestimated the distance by 9.8% and 7.7% when a 25 year old male triathlete ran at a mean speed of 4.8 ± 0.2 m·s^{-1} and 4.1 ± 0.1 m·s^{-1}, respectively (Gray et al., 2010). However, once the inward lean is accounted for on such circular circuits the underestimation may be less. Thus, although there are some methodological limitations with the published studies, it seems the 1 Hz GPS may underestimate (only one study has shown a slight overestimate) distances covered when the speed is fast (> 4.0 m·s^{-1}) and particularly during the acceleration phase. Hence, both researchers and practitioners need to be aware that sprint distances may be underestimated by 1 Hz GPS devices.

The inter-model reliability of the 1 Hz GPS has been examined in several studies, with the method being that participants run the same course on a number of occasions while wearing two or more of the same devices. The reported coefficient of variations for different studies involving different courses and different speeds are summarised in tables 2.12-2.14 and a brief written description is included here. When linear and non-linear long distances (40-771 m) were covered with a mixture of speeds (walking to sprinting), lower coefficients of variation were reported regardless of GPS brand and type (MinimaxX (Catapult Innovations): 7.0-17.5% (Jennings et al., 2010), SPI elite (GPSport): 3.6-4.0% (Coutts and Duffield, 2010), WiSPI elite (GPSport): 7.1-7.2% (Coutts and Duffield, 2010), SPI-10 (GPSport): 4.5-6.4% (Coutts and Duffield, 2010). Larger coefficients of variation were observed when short distances (< 40 m) were covered at high speeds (around 4 $m \cdot s^{-1}$ and faster) and during acceleration (MinimaxX (Catapult Innovations): 14.0-77.2% (Jennings et al., 2010), SPI elite (GPSport): 11.2-15.4% (Coutts and Duffield, 2010), WiSPI elite (GPSport): 11.5-20.4% (Coutts and Duffield, 2010), SPI-10 (GPSport): 30.4-32.4% (Coutts and Duffield, 2010). However, lower coefficients of variation were observed when short distances were covered at slow speeds compared to a high speeds (MinimaxX, Catapult Innovations: Jog vs. Stride vs. Sprint = 20.9-34.7% vs. 33.3-58.8% vs. 44.9-77.2%) (Jennings et al., 2010), SPI-10, GPSport: mean speed of 1.7 ± 0.1 $m \cdot s^{-1}$ vs. 2.9 ± 0.1 $m \cdot s^{-1}$ = 2.1-3.6% vs. 9.5-15.3% (Duffield et al., 2010). Moreover, a lower 95% coefficient of variation (defined as $(1.96 \cdot SD) \cdot mean^{-1}$ (Atkinson and Nevill, 1998)) was observed when a 200 m course was linear (1.46-3.38%) rather than non-linear (1.63-6.04%) (Gray et al., 2010). Overall these various authors have concluded that 1 Hz GPS has an acceptable inter-model reliability for estimating long distances covered, for example during the course of a match. However, the reliability declines when short distances over both linear and non-linear courses are covered at high speeds or during acceleration. Moreover, reliability of the system can vary largely depending on the manufacturer and type. Therefore, practitioners need to consider the capability of the system especially when activities with high speed and acceleration are included. The 1 Hz device with the best reliability seems to be the SPI elite which has a reliability of ~4% for long distances, relevant for the total distance covered during a match, and of 11-15% for high speeds relevant for sprints within a match.

Table 2.12 Reliability of 1 Hz GPS in circuits at different speeds.

Type of GPS	Protocol	Distance and/or speed	Coefficient of variation (%)	Authors
SPI elite (GPSport, Australia)	Six laps around a marked 128.5 m running circuit involving walking, jogging, fast running, sprinting and standing still with different type of change of directions.	Lap Bout (6 laps) > 5.6 $m \cdot s^{-1}$ > 4 $m \cdot s^{-1}$ < 4 $m \cdot s^{-1}$	4 3.6 15.4 11.2 4.3	Coutts and Duffield, 2010
WiSPI elite (GPSport, Australia)	Six laps around a marked 128.5 m running circuit involving walking, jogging, fast running, sprinting and standing still with different type of change of directions.	Lap Bout (6 laps) > 5.6 $m \cdot s^{-1}$ > 4 $m \cdot s^{-1}$ < 4 $m \cdot s^{-1}$	7.2 7.1 11.5 20.4 12.5	Coutts and Duffield, 2010
SPI-10 (GPSport, Australia)	Six laps around a marked 128.5 m running circuit involving walking, jogging, fast running, sprinting and standing still with different type of change of directions.	Lap Bout (6 laps) > 5.6 $m \cdot s^{-1}$ > 4 $m \cdot s^{-1}$ < 4 $m \cdot s^{-1}$	6.4 4.5 30.4 32.4 5.3	Coutts and Duffield, 2010

Table 2.13 Reliability of 1 Hz GPS in short straight courses at different speeds.

Type of GPS	Protocol	Distance and/or speed	Coefficient of variation (%)	Authors
WiSPI elite (GPSport, Australia)	Covered a straight 200 m course with various speeds.	Mean speed = ~1.6 m·s^{-1}	2.02	Gray et al., 2010
		Mean speed = ~3.5 m·s^{-1}	2.33	
		Mean speed = ~5.0 m·s^{-1}	1.46	
		Mean speed = 6-7 m·s^{-1}	3.38	
	(95% coefficient of variation (defined as (1.96·SD)·mean^{-1} (Atkinson and Nevill, 1998))			
MinimaxX (Catapult Innovations, Australia)	Covered a straight 40 m course with a lap time at 10 and 20 m.	Walk	10 m = 30.8 20 m = 20.4 40 m = 7.0 20-40 m = 17.5	Jennings et al., 2010
		Jog	10 m = 34.7 20 m = 20.9 40 m = 9.4 20-40 m = 21.0	
		Stride	10 m = 58.8 20 m = 33.3 40 m = 10.5 20-40 m =14.0	
		Sprint	10 m = 77.2 20 m = 44.9 40 m = 11.5 20-40 m =14.0	

Table 2.14 Reliability of 1 Hz GPS in non-linear courses at different speeds.

Type of GPS	Protocol	Distance and/or speed	Coefficient of variation (%)	Authors
WiSPI elite (GPSport, Australia)	Covered a non-linear 200 m course with various speeds.	Mean speed = ~1.6 $m \cdot s^{-1}$	3.43	Gray et al., 2010
		Mean speed = ~3.5 $m \cdot s^{-1}$	1.63	
		Mean speed = ~5.0 $m \cdot s^{-1}$	2.75	
		Mean speed = 6-7 $m \cdot s^{-1}$	6.04	
	(95% coefficient of variation (defined as $(1.96 \cdot SD) \cdot mean^{-1}$ (Atkinson and Nevill, 1998))			
MinimaxX (Catapult Innovations, Australia)	Covered a 10 m x 4 zig-zag course with three 90º change of directions	Walk	11.6	Jennings et al., 2010
		Jog	9.0	
		Stride	12.2	
		Sprint	10.7	
	Covered a 5 m x 8 zig-zag course with seven 90º change of directions	Walk	17.5	Jennings et al., 2010
		Jog	8.6	
		Stride	10.8	
		Sprint	12.0	

Table 2.14 (continued) Reliability of 1 Hz GPS in non-linear courses at different speeds.

Type of GPS	Protocol	Distance and/or speed	Coefficient of variation (%)	Authors
SPI-10 (GPSport, Australia)	Covered a 26 m rectangle shaped course at two different speed	Mean speed = 1.7 m·s^{-1} Peak speed = 2.6 m·s^{-1}	Distance = 3.6 Mean speed = 2.1 Peak speed = 2.3	Duffield et al., 2010
		Mean speed = 2.9 m·s^{-1} Peak speed= 4.9 m·s^{-1}	Distance = 9.5 Mean speed = 11.1 Peak speed = 15.3	
	Moved side to side over 4 m	Distance = 37.0 m Mean speed = 1.1 m·s^{-1} Peak speed = 2.6 m·s^{-1}	Distance = 3.6 Mean speed = 3.9 Peak speed = 5.8	
	Moved side to side over 8 m	Distance = 33.7 m Mean speed = 1.7 m·s^{-1} Peak speed = 3.9 m·s^{-1}	Distance = 7.6 Mean speed = 5.6 Peak speed = 12.6	

(Distance and speeds were estimated using a 22 camera VICON motional analysis system (Oxford Metrics, UK)).

2.3.2 Match performance

Elite senior soccer players

From recent studies which used computer pen and tablet, manual video coding or automatic video recording showed that male professional soccer players were shown to cover 10-14 km in a 90 minute match (Bradley et al., 2009; Burgess et al., 2006; Di Salvo et al. 2007; Di Salvo et al., 2009; Mohr et al., 2003; Rampinini et al., 2007a; Rampinini et al., 2007b) and the players performed several different types of ball and non-ball activities during a match (Reilly, 2003). The methods employed in the previous studies are listed in table 2.12.

The activities categorised according to linear speed have been standing, walking, jogging or low intensity running, running or moderate intensity running, high intensity running and sprinting (Bradley et al., 2009; Burgess et al., 2006; Di Salvo et al. 2007; Di Salvo et al., 2009; Mohr et al., 2003; Rampinini et al., 2007a; Rampinini et al., 2007b). Although various speed ranges have been employed (table 2.13), the most commonly used speed ranges were 0 $km \cdot h^{-1}$ to ~7 $km \cdot h^{-1}$ for standing and walking, ~7 $km \cdot h^{-1}$ to ~14 $km \cdot h^{-1}$ for jogging or low intensity running, ~14 $km \cdot h^{-1}$ to ~19 $km \cdot h^{-1}$ for running or moderate intensity running and ~19 $km \cdot h^{-1}$ to ~25 $km \cdot h^{-1}$ for high intensity running. Any running with a speed faster than high intensity running has been categorised as sprinting (Bradley et al., 2009; Burgess et al., 2006; Di Salvo et al., 2007; Di Salvo et al., 2009; Rampinini et al., 2007a; Rampinini et al., 2007b).

For adult players, the distances covered were 3400-4000 m for standing and walking, 4000-5000 m for jogging or low intensity running, 1700-1850 m for running or moderate intensity running, ~700 m for high intensity running and 200-650 m for sprinting (Bradley et al., 2009; Burgess et al., 2006; Mohr et al., 2003; Rampinini et al., 2007a). The percentage of time spent in each category during a match were 30-65% for standing and walking, 20-40% for jogging or low intensity running, 6.4% for running or moderate intensity running, 2% for high intensity running and 0.6-2.3% for sprinting (Bradley et al., 2009; Burgess et al., 2006; Mohr et al., 2003; Rampinini et al., 2007a). A range of mean single sprint distance was 7-19 m (Bradley et al., 2009; Di Salvo et al., 2007; Mohr et al., 2003) and sprints were performed 3-40 times in a 90 minute match (Bradley et al., 2009; Di Salvo et al., 2007; Mohr et al., 2003).

Table 2.15 Authors, standard, method of match analysis and rationale or method for deciding speed zones.

Authors	Standard	Method	Rationale or method for deciding speed zones
Reilly and Thomas, 1976	Top English league	Video recording	Mean stride length for each activity while moving 15 m were identified
Withers et al., 1982	National league of Australia	Video recording	After 3-5m walk, players walked, jogged, strided or sprinted diameter of centre circle and mean stride length for each activity was calculated.
Mayhew & Wenger, 1985	North American Soccer League	Video recording	Similar method developed by Brodie (1981)
Bangsbo et al., 1991	Best Danish League	Video recording	Participants were videotaped while doing specific activities and mean velocities for each activity were determined
Rienzi et al., 2000	English Premier League & South American International	Video recording	Activities were categorised based on the estimates of a trained observer using stride frequencies per second
Mohr et al., 2003	Top Italian and UEFA Champions league	Video recording	Participants were videotaped while doing specific activities and mean velocities for each activity were determined

Table 2.15 (continued) Authors, standard, method of match analysis and rationale or method for deciding speed zones.

Authors	Standard	Method	Rationale or method for deciding speed zones
Burgess et al., 2006	Australian national soccer league	Video footage using track performance software	Not stated
Rampinini et al., 2007a	Top professional players compete in UEFA Champions league	Multi-camera system, Prozone (Di Salvo et al., 2006)	Not stated
Rampinini et al., 2007b	Top professional players compete in UEFA Champions league	Multi-camera system, Prozone (Di Salvo et al., 2006)	Not stated
Di Salvo et al., 2007	Spanish premier & UEFA Champions league	Multi-camera system, Prozone (Di Salvo et al., 2006)	Not stated
Di Salvo et al., 2009	English Premier League	Multi-camera system, Prozone (Di Salvo et al., 2006)	Not stated
Bradley et al., 2009	English Premier League	Multi-camera system, Prozone (Di Salvo et al., 2006)	Not stated

Table 2.16 Authors and speed zones employed.

Authors	**Speed zones (km·h^{-1})**						
Reilly and Thomas, 1976	Not applicable						
Withers et al., 1982	Not applicable						
Mayhew & Wenger, 1985	Standing	Walking	Jogging			Running	
	No locomotor movement	Strolling locomotor movement	Nonpurposeful, slow running where the individual did not have specific goal for his movements			Combined striding and sprinting - running with purpose and effort	
Bangsbo et al., 1991	Standing	Walking	Jogging	Low speed running	Moderate speed running	High speed running	Sprinting
	0	6	8	12	15	18	30
Rienzi et al., 2000	Not applicable						
Mohr et al., 2003	Standing	Walking	Jogging	Low speed	Moderate speed	High speed	Sprinting
	0	6	8	12	15	18	30
Burgess et al., 2006	Walking		Jogging	Striding		Sprinting	Maximum speed zone
	0 - 7		7 - 12	12 – 18		18 - 24	24 and over

Table 2.16 (continued) Authors and speed zones employed.

Authors	**Speed zones (km·h^{-1})**						
Rampinini et al., 2007a	Standing	Walking	Jogging	Running		High speed running	Sprinting
	0.0 - 0.7	0.7 - 7.2	7.2 - 14.4	14.4 - 19.8		19.8 - 25.2	> 25.2
Rampinini et al., 2007b	Standing	Walking	Jogging	Running		High speed running	Sprinting
	0.0 - 0.7	0.7 - 7.2	7.2 - 14.4	14.4 - 19.8		19.8 - 25.2	> 25.2
Di Salvo et al., 2007	Stopping to jogging			Low speed	Moderate speed	High speed	Sprints
	0 - 11.0			11.1 - 14.0	14.1-19.0	19.1 - 23.0	> 23.0
Di Salvo et al., 2009	Standing	Walking	Jogging	Running		High speed running	Sprinting
	0.0 - 0.7	0.7 - 7.2	7.2 - 14.4	14.4 - 19.8		19.8 - 25.2	> 25.2
Bradley et al., 2009	Standing	Walking	Jogging	Running		High speed running	Sprinting
	0.0 - 0.6	0.7 - 7.1	7.2 - 14.3	14.4 - 19.7		19.8 - 25.1	> 25.1

Elite youth soccer players

In youth soccer, there have been a limited number of match analysis studies. In an 11 a side match (two 30 minute halves) played on a regular size pitch, the U15 Brazilians covered 7077 m (Pereira Da Silva et al., 2007). Castagna and colleagues analysed a 60 minute (30 minute each half) soccer match of 14 years old Italians who belonged to a national youth soccer academy (Federazione Sammarinese Giuoco Calcio, San Marino) using GPS. Speed categories created were 0-0.4 $km \cdot h^{-1}$ (standing), 0.4-3.0 $km \cdot h^{-1}$ (walking), 3.0-8.0 $km \cdot h^{-1}$ (jogging), 8.0-13.0 $km \cdot h^{-1}$ (medium-intensity running), 13.0-18.0 $km \cdot h^{-1}$ (high-intensity running) and > 18.0 $km \cdot h^{-1}$ (sprinting). The total distance covered during the match was 6173 m and the players covered 508 m by walking, 2981 m by jogging, 1694 m by medium-intensity running, 741 m by high intensity running and 234 m by sprinting (Castagna et al., 2009).

Castagna and colleagues (2003) also analysed a 60 minute (30 min each half) soccer match of 11 years old (mean) Italian players using triangular surveying method and created four speed categories which were 0-8 $km \cdot h^{-1}$, 8.1-13.0 $km \cdot h^{-1}$ (medium intensity running), 13.1-18.0 $km \cdot h^{-1}$ (high intensity running) and > 18.0 $km \cdot h^{-1}$ (maximal intensity running). The mean distances covered were 4344 m for 0-8 $km \cdot h^{-1}$, 986 m for medium intensity running, 468 m for high intensity running and 114 m for maximum intensity running. Also in 11 year old Italian soccer players, Capranica et al. (2001) found that standing and walking accounted for 42% of the match duration from a manual video coding analysis. However, the percentage of time spent on standing and walking was reported to be higher for older age groups. Manual video recording analyses of Danish elite soccer players (three of the most successful clubs in Denmark) with a mean chronological age of 12.6 and 14.0 years showed that the percentage of time spent on standing and walking were 60.7% and 56.9% of total match time, respectively. Also, 31.3% and 34.0% of the match-time was spent on jogging and 7.9% and 9.0% of the match-time was spent on high intensity running (including sprinting) by the younger and older age groups, respectively (Stroyer et al., 2004). Thus there is a dearth of information regarding the match analysis of youth players as the studies were only conducted on 11, 12, 14 and 15 years old soccer players and they were from limited countries.

2.3.3 Comparison between the first and second halves

Elite senior soccer players

When adult professional players' performances during the first and second halves were compared, distances covered were shorter on standing and walking/jogging, longer on low (Bradley et al., 2009) and moderate intensity running in the first half (Bradley et al., 2009; Di Salvo et al., 2007; Mohr et al., 2003), and no differences were found in high speed running and sprinting between the halves (Bradley et al., 2009; Burgess et al., 2006; Di Salvo et al., 2007). Moreover, it was reported that high speed running was performed significantly less frequently in the second half (Di Salvo et al., 2009) and mean single sprint distance was shorter in the first half compared to the second half (Mohr et al., 2003). The findings were similar when expressed as the percentage of time spent at different speeds except that the percentage of time spent in high speed running and sprinting has been reported to be similar in each half (Bradley et al., 2009; Burgess et al., 2006; Di Salvo et al., 2007); or less in the second half (Di Salvo et al., 2009).

Elite youth soccer players

In 11 year old Italian soccer players, Capranica et al. (2001) showed that percentage of time spent on standing and walking was similar in the first and second halves. However, elite Danish soccer players (three of the most successful clubs in Denmark) with a mean chronological age of 12.6 and 14.0 spent more time on walking and less time on jogging and undertaking medium intensity running in the second half (Stroyer et al., 2004). However, there were no significant differences between halves for the distance covered by high and maximum intensity running (Castanga et al., 2003). Also, for maximum intensity running, no significant difference was reported in time spent and number of bouts performed during the first and second halves (Castanga et al., 2003). However, 14 years old elite youth soccer players from San Marino showed an decrement in moderate intensity running distance in the second half compared to the first half (first half vs. second half: 905 ± 313 vs. 789 ± 271; $p = 0.003$). Moreover, it was reported that total distance covered during the first and second halves (3149 ± 368 vs. 3024 ± 387; $p = 0.003$) were significantly different (Castagna et al., 2009). Hence, the differences in match activities between the first and second halves exist in elite youth soccer players. However, the differences in match activities between the first and second halves were only investigated in 11, 12 and 14 years old elite youth soccer players.

Therefore, the differences in match activities between the first and second halves in 9, 10, 13, 15, 16, 17 and 18 year old elite soccer players need to be examined.

2.3.4 Different playing positions

In adult players, distance run and the time spent on different activities during a match have been shown to vary by playing position. When the distance covered was compared according to playing position for adult professional players, total distance covered during a match was the longest for midfielders and the shortest for centre backs and forwards (Bradley et al., 2009; Rampinini et al., 2007b). Full backs were reported to cover the same distance as forwards and centre backs (Bradley et al., 2009) or a shorter distance than midfielders but longer than centre backs and forwards (Rampinini et al., 2007b). Centre backs and centre midfielders were shown to sprint the least distance and wide midfielders sprinted the longest distance in a match (Bradley et al., 2009; Di Salvo et al. 2007; Di Salvo et al., 2009). Full backs were shown to sprint similar (Bradley et al., 2009; Di Salvo et al. 2007) or less (Di Salvo et al., 2009) distance compared to wide midfielders and, forwards were also shown to sprint a similar (Di Salvo et al. 2007; Di Salvo et al., 2009) or less (Bradley et al., 2009) distance compared to wide midfielders.

For high intensity running, wide midfielders were reported to cover the longest distance followed by full backs and centre midfielders and centre backs cover the shortest distance in a match (Bradley et al., 2009; Di Salvo et al. 2007; Di Salvo et al., 2009). Forwards were reported to cover a similar distance to full backs and centre midfielders by high intensity running (Bradley et al., 2009; Di Salvo et al. 2007) or covered more than full backs and centre backs and, less than wide midfielders (Di Salvo et al., 2009). For moderate intensity running, midfielders were reported to cover the longest distance followed by full backs whereas, centre backs covered the shortest distance (Di Salvo et al. 2007; Rampinini et al., 2007b). Forwards were shown to cover the same distance as centre backs (Rampinini et al., 2007b) or full backs (Di Salvo et al. 2007).

In professional soccer players, the highest percentage of time spent on jogging during a match was demonstrated by centre backs and forwards, followed by full backs and then centre midfielders (Rampinini et al., 2007b). For standing and walking, the highest percentage of time was spent by centre backs and forwards, and the least percentage of time was spent by centre midfielders. Full backs spent the same percentage of time in standing and walking as all the other positions (Rampinini et al., 2007b). There are no studies examining positional differences with respect to match activities in youth soccer players. One study has examined the heart rate response to match play by position in youth soccer players and there was a tendency for a higher mean heart rate for forwards than defenders (Stroyer et al., 2004).

2.4 Relationship between physical characteristics, physical performance and match performance

Only three studies have examined the relationship between field test performance and match performance and the participants recruited in two of these studies were elite professional soccer players.

In one study, 18 elite senior professional soccer players participated in the Yo-Yo intermittent recovery test (level 1; see Chapter 3) and were video analysed to determine their match running performance. A significant relationship ($p < 0.05$, $r = 0.71$) was found between performance during the Yo-Yo intermittent recovery test (level 1) and the distance covered by high intensity running (> 15 $km \cdot h^{-1}$) during a match. Moreover, a significant relationship ($r = 0.58$, $p < 0.05$) was found between the Yo-Yo intermittent recovery test (level) and the distance covered by sum of high speed running (> 18 $km \cdot h^{-1}$) and sprinting (> 30 $km \cdot h^{-1}$) during a match. No other significant relationships were reported (Krustrup et al., 2003).

In a more recent study, 18 elite professional senior soccer players completed an incremental field test (to measure endurance), repeated sprint ability test (40 m x 6) and counter movement jump with arms (see Chapter 3). Match running performance was analysed using a video computerised, semi automatic, match analysis image recognition system using 6 cameras (Prozone, Leeds, England). Running speed of high intensity running, very high intensity running and sprinting was defined as > 14.4 $km \cdot h^{-1}$, > 19.8 $km \cdot h^{-1}$ and > 25.2 $km \cdot h^{-1}$, respectively. A significant relationship was found between peak speed in the incremental test and total distance covered ($r = 0.58$, $p < 0.01$), distance covered by high intensity running ($r = 0.65$, $p < 0.01$) and very high intensity running ($r = 0.64$, $p < 0.01$) during a match. Moreover, a significant relationship was found between repeated sprint ability calculated by mean of six sprint times and sprinting distance ($r = 0.65$, $p < 0.01$) and distance covered by very high intensity running ($r = 0.60$, $p < 0.01$) during a match. There were no other significant relationship between field test performance and match running performance found in the study (Rampinini et al., 2007a).

In the only study to examine elite youth players, 21 soccer players from the national youth soccer academy of San Marino who were 14.2 (± 0.2) years old took part in a study which involved a match analysis using GPS (SPI Elite, GPSport, Australia) and the Yo-Yo intermittent recovery test (level 1). The match activities with a running speed of 13.0-18.0 km·h^{-1} and > 13.0 km·h^{-1} were categorised in high intensity running and high intensity activity, respectively. The results showed that there was a significant relationship between the performance from the Yo-Yo intermittent recovery test (level 1) and, distance covered by high intensity activities (r = 0.77) and high intensity running (r = 0.71) and total distance covered during a match (r = 0.65) (Castagna et al., 2009). Thus, overall there is a dearth of information regarding the relationship between field test and match performance in elite senior and youth players.

2.5 Biological maturity

Biological maturity is a well known factor influencing body size in adolescent boys (Malina, 1988; Yague and De La Fuente, 1998). Also for some sports such as swimming, tennis and athletics it has been shown that athletes in national age group squads are of advanced maturity (Baxter-Jones and Helms, 1996). Moreover, elite youth soccer players who were born early in the competition year are favoured for selection more than their peers who were born later in the same year (Carling et al., 2009). However, the players who mature late may 'catch-up' when they reach young adulthood and the age at which maturation occurred (early vs. late) did not lead to a difference in the percentage of players in each category who went on to become professional players (Carling et al., 2009). Therefore, it would seem to be important not to rate players largely based on physical characteristics or physical performance during the period when they have a large variation in maturity level. It is also important to discover when the development in physical characteristics ceases as the concerns regarding maturational changes will not exist after this point. In this section, the different methods to assess biological maturity and the influence of biological maturity on anthropometry, speed, standing vertical jumps, endurance ability and playing positions in soccer players are discussed.

2.5.1 Methods for determining maturity

The methods to assess biological maturity were created and these include assessment of dental age (Malina et al., 2004a), secondary sexual maturation (Tanner, 1962), skeletal age (Tanner et al., 2001) and prediction of chronological age at peak height velocity (PHV) (Mirwald et al., 2002). Dental age involves wide assessment techniques with a limited applicability (Malina et al., 2004a). Secondary sexual maturation can only be used for adolescents and while traditionally medical specialists have assessed sexual maturity, it is now common for the participants themselves to undertake the assessments due to ethical concerns. However, self-assessment has been reported to possess sufficient accuracy and reliability (Petersen et al., 1988). Skeletal maturity is generally accepted as the best method (Malina et al., 2004a). However, it is costly and requires specialised equipment and the use of radiation can raise health and safety issues. Moreover, chronological age at PHV can be predicted by taking a series of standing height measurements over years (Malina, 1988). Furthermore, measurements including standing height, sitting height, body mass and chronological age collected from a single session allows an estimation of chronological age at

PHV and this method can include participants with a chronological age range of 7 to 18 years (Mirwald et al., 2002). It was recently suggested that the bone age is very important to understand anthropometric differences and sexual maturation is most important to understand motor performance differences (Capela et al., 2004b).

2.5.2 The effect of maturity on the physical characteristics of elite youth soccer players

Standing height, body mass and stage of genital and pubic hair development (Tanner, 1962) were determined for 11-17 year old English League players (N = 64). Sexual maturity was determined by taking a mean of stage of genital and pubic hair development (Tanner, 1962). It was shown that standing height and body mass of elite youth soccer players was positively influenced by sexual maturity (Jones and Helms, 1993).

Cross-sectional research was conducted to investigate the relationship between maturity, standing height and body mass of elite youth soccer players. The research consisted of 69 players (chronological age range: 13.2-15.1 years) competing in the highest division of the Portuguese national league in their age group. The study used stage of pubic hair development (Tanner, 1962) to assess biological maturity of the players. The results showed a significant relationship ($P < 0.05$) between maturity status, standing height and body mass (Malina et al., 2004b).

When maturity was assessed using skeletal age in elite Portuguese soccer players, standing height of the players in the 11-12, 13-14 and 15-16 age groups and body mass of the players in the 11-12 and 13-14 age groups were influenced positively by biological maturity (Malina et al., 2000). Moreover, the standing height of English Football Academy players (U12-U15 age groups) and body mass (U12-U16 age groups) was also positively affected by biological maturity (Hulse, 2010, unpublished). Thus, only three studies have examined the effect of maturity on the physical characteristics of elite youth soccer players and only standing height and body mass have been examined.

2.5.3 The effect of maturity on the speed of elite youth soccer players

There are some apparent relationship between maturity and linear sprint speed.
Stage of pubic hair development was used to examine the influence of sexual maturity on 10 and 20 m sprint performance in U9-U18 English Premier League Academy players. The study showed that the U13 players in higher stage showed a significantly better 10 m sprint

time compared to the players in lower stage. Moreover, significantly faster 20 m sprint time was observed in the players with an advanced maturational status compared to the players with less advanced maturational status in the U11, U12 and U13 age groups (Hulse, 2010, unpublished).

Portuguese players (N = 70, age 14-16) were assessed for 30 m sprint speed with split time at 5, 15 and 25 m and skeletal maturity based on radiographs of the hand and wrist bones (Tanner et al., 2001). There was a significant positive relationship ($P < 0.01$) between skeletal maturity and sprint speed (Capela et al. 2004b). When stage of pubic hair development was employed to assess biological maturity instead of skeletal age, Malina et al. (2004b) showed a similar finding to Capela et al. (2004b). The participants were 69 youth soccer players (age range = 13.2-15.1 years) who played in the highest division for their age group. The results showed that the players in stage 4 and 5 of pubic hair development performed significantly ($P < 0.05$) better than the players in stage 1 and 2 of pubic hair development (Malina et al. 2004b).

2.5.4 The effect of maturity on the standing vertical jump performance of elite youth soccer players

The research findings relating to the effect of maturity on vertical jump performance are equivocal. One study examined 69 youth soccer players (chronological age range: 13.2-15.1 years) who played for the highest division for their age group. The players performed a counter movement jump with arms and were assessed for biological maturity using stage of pubic hair development (Tanner, 1962). Whilst controlling chronological age, standing height and body mass, analysis of covariance was used to analyse the relationship between biological maturity and the counter movement jump with arms. The results did not show a consistent trend and only showed that the players in stage 4 of pubic hair development performed significantly better than the players in stage 2 and 3 (Malina et al., 2004b). Hulse (2010, unpublished) also employed stage of pubic hair development (Tanner 1962) to examine an influence of sexual maturity on performance of squat jump, counter movement jump without and with arms in the U9-U18 English Premier League Academy players. The study showed that the U12, U13, U15 and U16 players in higher stage performed significantly better in standing vertical jumps compared to the players in a lower stage who belonged to the same age group.

In a study conducted by Capela and colleagues (2004b), 70 Portuguese players aged between 13 and 16 were recruited. They performed the counter movement jump with arms and were assessed for their skeletal maturity based on radiographs of the hand and wrist bones (Tanner et al., 2001) and sexual maturity using stage of pubic hair development (Tanner, 1962). The participants were divided into 4 sub-groups according to bone age: 1-13 years, 2-14 years, 3-15 year and 4-16 years. When the participants were divided according to skeletal age, a difference existed between 13 and 16 years old and between 14 and 16 years old in performance of counter movement jump. When sexual maturity was used to determine biological maturity, a relationship was found between the counter movement jump with arms and biological maturity ($P < 0.05$). However, in another analysis of the same data when the players were sub-divided into different chronological age groups, no such relationships were found between skeletal age and jump performance (Capela et al., 2004b). Therefore, the effect of maturity on jump performance is unknown.

2.5.5 Endurance

It has been suggested that peak oxygen uptake expressed in absolute term and relative to body mass is positively influenced by sexual maturity (Jones and Helms, 1993). However, in this study examining 64 (11-17 years olds) English players, chronological age was not controlled between the players in different stage of genital and pubic hair development and statistical analysis was not undertaken on the data (Jones and Helms, 1993).

In another study, 69 Portuguese youth soccer players (13-15 years) who competed in the highest division for their age group completed the Yo-Yo intermittent endurance test (Level 1) (Bangsbo, 2005) and biological maturation was measured using stage of pubic hair development. Endurance of the soccer players in stage 1 of pubic hair development was lower than the players in all other stages but there were no difference between players in stage 2 and 5 of pubic hair development (Malina et al., 2004b). Thus, there are only two studies which have examined the impact of maturity on endurance in elite youth soccer players and the findings are not conclusive.

2.6 The Long-Term Athlete Development Model

The Long-Term Athlete Development Model is claimed to provide guidance to the activities that should be undertaken at various ages and stages of development for the optimum progression of playing standards in young players and ultimately in senior performers (Balyi and Hamilton, 2004). There are two variants on the model, the early and late specialisation models with the former claimed to be suitable for diving, figure skating, gymnastics and table tennis and the latter claimed to be suitable for track and field athletics, combative sports, cycling, racquet sports, rowing and all team sports which require a generalised approach to early training. The former model consists of four stages and the later model consists of six stages. The stages included in late specialisation model in males are: FUNdametal stage (6-9 years); Learning to Train (9-12 years); Training to Train (12-16 years); Training to Compete (16-18 years); Training to Win (18 years old older); Retirement/retainment (retired performers) (Balyi and Hamilton, 2004). In each of the first five stages of the late specialisation model there are recommendations for key aspects to focus upon in training (e.g. skills, coordination for basic movements, endurance etc) and guidance is provided on delivery and on the training to competition ratio. Moreover, within the model the phrase "window of opportunity" is used to indicate a period when trainability of certain attribute is claimed to accelerate and it is suggested that the performers who miss this opportunity will not reach their full potential. It is claimed there is a "window of opportunity" for physical literacy (6-12 years old), motor skill (9-12 years old), speed (7-9 and 13-15 years old), strength (12-18 months following PHV) and 'aerobic ability' (from the onset of PHV). There is an emphasis within the literature concerning the model on the influence of biological maturity on the period of trainability and it is recommended that the timing of the start of more serious training on endurance and strength needs to be individualised as timing of PHV differs between individuals (Balyi and Hamilton, 2004).

The English Football Association has produced its own Long-Term 'Player' Development Model (Simmons, 2005), based on the Long-Term Athlete Development Model (Balyi and Hamilton, 2004), and this model has been recommended to youth development organisations in English football clubs as a guide for appropriate activities for the development of young players. However, the FA's model focuses more on "a fully inclusive participation policy for all" rather than focusing on elite players. Hence, the model is very flexible and can be easily used by coaches and practitioners working with players across a wide range of playing standards. The model provides eight stages, opposed to six in the original model, and the model includes a wider age range. The stages are: FUNdametal stage (5-8 years); Enjoying the practice (8-11 years); Developing practice (11-14 years); Understanding competition (14-16 years); Training for competition (16-18 years); Developing winning (18-20 years); Training to Win (20 years old older); Retirement/retainment (any age). The FA has included recommendations on psychological, social and, soccer related technical and tactical aspects in addition to the physical and general technical recommendations which were contained in the original model. However, the FA's model does not include any modifications or further recommendations concerning the physical development of players in comparison with the original model.

Relevance of the Long-Term Athlete Development Model for Adaptations to Endurance Training

The Long-Term Athlete Development Model (Balyi and Hamilton, 2004) stated that the "window of opportunity" for 'aerobic' training begins with onset of PHV. Two studies (Tolfrey et al. 1998; Williams et al. 2000) have indeed reported that there were no changes in maximum oxygen uptake at 10 years of age after 10-12 weeks of endurance training which supports the idea that the adaptations to training may come at a later age. However, other studies offer no such support for the window of opportunity idea. For example one study which included 10, 13 and 16 years old twin boys, with one twin taking part in 10 weeks of endurance training (4 days a week) and another twin acting as control, found that the 10 and 16 years old participants improved their peak oxygen uptake by 13 and 15%, respectively, but the improvement in 13 years olds was only about 10% (Weber et al., 1976). These data do not fit with the idea of any window of opportunity at the onset of PHV. Furthermore another study found no increases in sensitivity to endurance training from the onset of PHV. This longitudinal study observed 12 boys from 3 years before PHV to 4 years after PHV (8 boys belonged to a running club participating in a regular training and 4 boys were not attending regular training in any sport). There was a slight increase in maximal oxygen uptake 6 months after PHV compared to that at onset of PHV in the training group, but there were no statistically significant differences. In the control group, maximal oxygen uptake started to decline after PHV (Sjodin and Svedenhag, 1992). Therefore, there are mixed findings regarding the period where 'aerobic' trainability increases in children and adolescents, if such a period occurs at all, and thus more comprehensive consistent evidence is required for practitioners and scientists to believe that such as 'window of opportunity' exists.

Relevance of the Long-Term Athlete Development Model for Adaptations to Speed and Co-ordination Training

In the Long-Term Athlete Development Model it is claimed that the "windows of opportunity" for speed and co-ordination training are between 7 and 9 years and between 13 and 15 years of age (Balyi and Hamilton, 2004). However, there is little evidence to support these claims in the literature as very few training studies have been undertaken with children and adolescents and the findings are equivocal. In one study sixteen soccer players (mean age 11 ± 0.5 years) were randomly assigned to a sprint-training group (STG = 7) or a coordination-training group (CTG = 9). The STG trained twice a week for 12 weeks and performed 20 repetitions of 10 and 20 m sprints and the CTG performed coordination training (e.g., speed ladder running) for the same training duration. Both groups significantly improved 20 m speed but there were no difference in magnitude of improvement between the groups (Venturelli et al., 2008). Hence, coordination training may assist in the development of sprint performance, but there was no information about the timing of changes in this study as only one group of individuals with an average age of 11 years participated. In a further study, an improvement in 30 m sprint performance was reported during the year before onset of PHV (13.8 ± 0.8 years) but, the performance plateaued or slightly declined during the 18 months after PHV. This change in the pattern of speed development may have been due to rapid physical growth which may have disrupted motor coordination (Philippaerts et al., 2006). It is possible therefore that work on co-ordination training through this period of rapid growth might enhance sprint performance, but there are no comparisons with training in other age groups and stages of puberty to support such claims. Furthermore, improvements in enzyme activity in response to sprint training have been shown in 11 years olds (Eriksson, 1980) and 16-17 year old boys (Fornier et al., 1982). In both training studies, the adaptations were less than those observed in training studies in adults and the training effect was no longer evident 6 months after the end of training (Fornier et al., 1982). Thus there is no evidence to suggest that adaptions to training are greater during any particular age group or period. Of course there will be a greater improvement in sprint performance during puberty (not necessarily due to training) then before or after puberty and in 10-14 year old soccer players a significant relationship has been found between changes in testosterone and changes in sprint performance (Gravina et al. 2008). There is some limited evidence to suggest improvements in sprint performance will be greater across the entire 11-18 age group in elite athletes (in training) in comparison with active school standard controls (Hemmings, 2006).

Relevance of the Long-Term Athlete Development Model for Adaptations to Strength Training

The Long-Term Athlete Development Model (Balyi and Hamilton, 2004) stated that strength is always trainable, but there is a "window of opportunity" 12-18 months following PHV This statement, that strength is always trainable is supported by training studies which showed an improvement in strength after eight to 12 weeks of training in prepubescent, pubescent and postpubescent boys (Lillegard et al., 1997; Pfeiffer and Francis, 1986; Vrijens, 1978). In one of these training studies , boys with a mean chronological age of 10.4 and 16.7 years performed 8-12 repetitions (70% of one repetition maximum) in eight different exercises for eight weeks (3 sessions a week). Both age groups improved strength, but the younger group only improved strength in exercises using the abdominal area and the back whereas the older group showed an improvement in strength in all exercises (Vrijens, 1978). Another study demonstrated an improvement in strength in prepubescent, pubescent and postpubescent males. The participants performed 9 exercises at 50, 75 and 100% (1 set each) of 10 repetitions maximum and the greatest increase in relative strength occurred among the prepubescent males (Pfeiffer and Francis, 1986). Moreover, boys with stage 1-2 (mean age = 11.2 years) and 3-5 (mean age = 14.0 years) of Tanner stages (Tanner, 1962) took part in 12 weeks of strength training (three one hour sessions a week). Each session involved three sets of ten repetitions (10 repetitions maximum) in six exercises. An improvement in strength was seen in all exercises in both groups and no differences in the magnitude of improvement were seen in any exercises between the age groups (Lillegard et al., 1997). Hence, strength does seem to be trainable at almost any maturational stages in children and adolescent as stated in the Long-term Athlete Development Model. However, there is no evidence from published training studies that a 'window of opportunity' for strength training occurs 12-18 months following PHV.

Relevance of the Long-Term Athlete Development Model for Adaptations to Power Training

The current Long-Term Athlete Development Model (Balyi and Hamilton, 2004) does not include a "window of opportunity" for power development. This is possibly because power is the product of force (strength) and velocity (speed) and “windows of opportunity” for these elements are included in the model. However, it has been previously suggested that due to the importance of muscular power for athletic success, inclusion of an appropriate period for maximum development of power may be necessary (Ford et al., 2011). The findings of previous literature reported in this section, would not support the idea that there may be a ‘window of opportunity’ for power training.

Summary

The Long-Term Athlete Development Model (Balyi and Hamilton, 2004) has been supported in recent coaching texts (Balyi and Stafford, 2005; Balyi and Williams, 2009) and is known to a wide range of practitioners across different sport and in football. However, there is a lack of scientific evidence to support the idea of ‘Windows of opportunity’ for the development of endurance, speed, strength and power. Therefore, the model, while of interest, does not have a full scientific underpinning.

2.7 Summary

While there have been numerous studies examining the physical characteristics and physical performance of senior professional players, the information on elite youth players is much more scarce. For elite youth players there is a dearth of information relating to body composition, to performance in terms of a range of sprint distances, ability and endurance, in relation to distances run during match play and in relation to the impact of chronological age and maturity on all variables.

Chapter 3

General methods

3.1 Participants

The participants were players in the U9-U18 squads of a Premier League Academy. The U9-U14 squads had three training sessions a week, the U15 and U16 squads had four training sessions a week and, the U17 and U18 squads had six training sessions a week. All squads had an average of one match a week during the season. Each player signed a consent form (Appendix A) and completed a health screen questionnaire (Appendix B) prior to participation in the study. The players were given a summary of the study which explained the tests and measurements included in the study (Appendix C). Also the players' parents, guardians or care-givers signed the consent form prior to the start of the study for those players under the age of 18 years (Appendix D). Participants were withdrawn from a particular test if they did not have a satisfactory health status which included injuries, not possessing inhaler when a player had asthma and/or if a member of their family under the age of 35 had died suddenly during or soon after exercise. The study was approved by Loughborough University Ethical Advisory Committee (Appendix E).

3.2 Measurements

Field tests were undertaken during two 2-3 hour sessions on separate days, within a 7 day period. A series of measurements were made and these were: standing height; sitting height; body mass; skinfolds; sexual maturation (U12-U14); 30 m sprint with split times at 5, 10, 15 and 20 m (figure 3.1); Slalom agility test (figure 3.2); 505 agility test (Draper and Lancaster, 1985, figure 3.3); squat jump; counter movement jump without arms; counter movement jump with arms; the Yo-Yo intermittent recovery test (level 1) (Bangsbo, 2005, figure 3.4); the Multi-stage fitness test (Ramsbottom et al., 1988). All the performance tests were separated by 3-5 min and only one endurance test was conducted in each session. The endurance test was always the last test to be conducted.

3.2.1 Anthropometric measurement

Standing height

Standing height was measured nearest to 0.1 cm using a stadiometer (Leicester height measure, SECA Ltd), with shoes removed.

Sitting height

Sitting height was measured nearest to 0.1 cm using a stadiometer using the same wooden box and two 1 m ruler taped onto the same wall.

Body mass

Body mass was measured nearest to 0.1 kg (Seca ltd, Germany). Players were wearing standard club training kit (T-shirt, a pair of shorts and a pair of socks) when weighed.

Skinfolds

Skinfold measurement was taken from 4 sites (biceps, triceps, subscapular and illiac crest) by International Society for Advancement of Kinanthropometry accredited anthropometrists using Harpenden calliper (Gaiam Pro). Body fat composition was estimated using the method investigated by Slaughter and colleagues (1988) and a sum of 4 skinfold sites was calculated.

3.2.2 Sexual maturity

The sexual maturation of the U12-U14 age groups was self-assessed using stages of genital development and pubic hair development (Tanner, 1962). The purpose and procedure for this assessment were explained to players by a same sex researcher and they were given a chance to ask questions. During the explanation, the players were shown a mirror and A2 size posters presenting the different stages of the genital development and pubic hair development of boys in a private room. Players were provided with an envelope containing separate A4 size pictures of the stages of development. During the individual assessment of their own stage of development alone in the private room, players were asked to write "A" on the side of the picture which was the closest to their stage of genital development and pubic hair development and to write "B" on the side of the picture which was the second closest to their stage of genital development and pubic hair development. The players were asked to only look at the size and shape of the genital and not at pubic hair when assessing stage of genital development and were asked to only look at pubic hair and not at the size of the testes, scrotum and penis when assessing stage of pubic hair development. The confidential nature of the data was explained and the players were informed that codes would be used instead of their names. It was made clear to the players that involvement was entirely voluntary and that they should not take part if they felt uncomfortable about the procedure. After the assessment, the envelope was sealed by the player and returned to the researcher.

3.2.3 Estimated chronological age at peak height velocity (PHV)

Estimated chronological age was calculated using a method reported by Mirwald et al. (2002). This method can predict chronological age at PHV with a reasonable degree of accuracy (R^2 = 0.89). The formula for the estimation is:
Estimated chronological age at PHV = chronological age - [-9.236 + (0.0002708*leg length*sitting height) + (-0.001663*chronological age*leg length) + (0.007216*chronological age*sitting height) + (0.02292*(body mass/standing height)*100]

When estimated chronological age at PHV (Mirwald et al., 2002) was used, the players from each squad (e.g., U10s) were separated into two groups based on their estimated chronological age at PHV (earlier maturers and later maturers). Then to ensure a large enough number of participants in each group for statistical analyses, the players were grouped as follows: U9/U10s, U11/U12s, U13/U14s, U15/U16s and U17/U18s.

3.2.4 Field testing

All of the field tests were conducted indoors and the surface was a new generation synthetic sports turf. All sprint and agility tests were timed by photoelectric timing gates (Brower timing system, Utah, USA) which used infra-red light and the timing gates were set at a distance to allow the light to travel 115 cm from the ground. The time was recorded to the nearest 0.01 s. A jump mat (Eleiko Sport AB, Sweden) was used to measure the height of three standing vertical jumps and the height was calculated using the time between take-off and landing.

30 m sprint

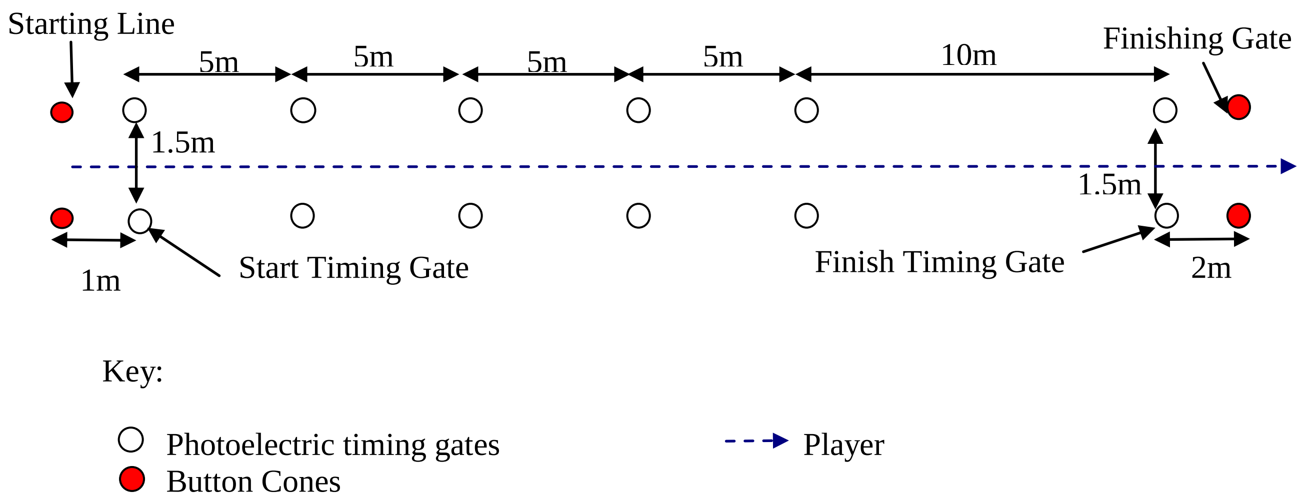


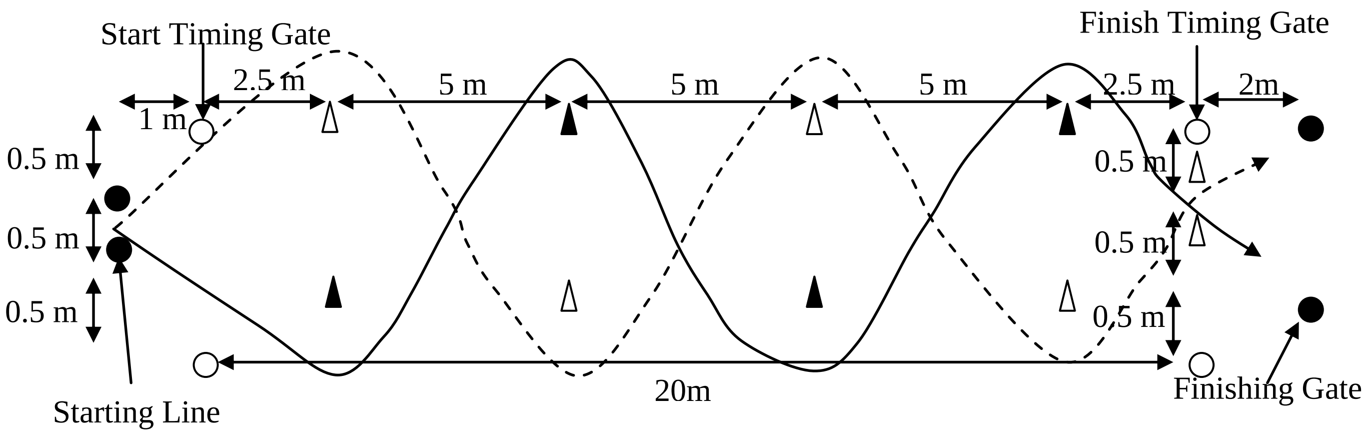
Figure 3.1 Set up of sprint test

One practice run was performed before the main trials. The participant stood with their preferred foot on the start line which was 1 metre behind the start timing gate. The participant started the run in their own time accelerating through the start timing gate and all the way through to the finishing gate. The times were recorded at 5, 10, 15, 20 and 30 m and participants performed 3 timed sprints with 2-5 min recovery (Balsom et al., 1992) in between sprints (The Football Association Medical and Exercise Science Department, 2004).

In a previous validity and reliability study, the U9-U18 English Premier League Academy players (N = 80, age = 13.2 ± 2.6 years) participated in a 20 m sprint test with a split time at 10 m on two occasions (7 days apart) and the tests were conducted between 17:30 and 19:30.

The sprint time at 10 and 20 m differed by only 0.01 s or less on the two occasions and the coefficient of variation was 1.7 to 1.9% in the U9-U11, U12-U14 and U15-U18 age groups. Moreover, coaches and fitness professionals of the players viewed speed as a most important attribute whilst sprint test performance distinguished between average and above average players classified by coaches and improved with age. Therefore, tests were concluded to be valid and reliable indicators of sprint performance (Hulse et al., 2012).

Slalom agility test



(Distance between 2 cones on finishing gate is measured from their base to base)
Key:

- Large Cones (height 45cm)
- Photoelectric timing gates
- Button Cones
- Players Run 1
- Players Run 2

Figure 3.2 Set-up of Slalom agility test

Participants performed one practice run for both run 1 and run 2, and run 1 was practiced first. The participants stood with their preferred foot on the start line which was 1 metre behind the start timing gate. Two valid runs were performed for both run 1 and run 2. Run 1 was performed first and the runs were performed alternately. A recovery time of 2-5 min was given in between the runs (Balsom et al., 1992). Participants were not permitted to touch any cones during the course of the agility test. If a cone was touched during a run, the run was repeated after 2-5 min recovery (The Football Association Medical and Exercise Science Department, 2004).

In a previous validity and reliability study, the U9-U18 English Premier League Academy players (N = 80, age = 13.2 ± 2.6 years) participated in a Slalom agility test on two occasions (7 days apart) and the tests were conducted between 17:30 and 19:30. The agility test performance differed by only 0.02 s or less on the two occasions and the coefficient of variation was 2.5 to 2.7% in the U9-U11, U12-U14 and U15-U18 age groups. Moreover, coaches of the players viewed agility as a most important attribute whilst the agility test performance distinguished between average and above average players classified by coaches and improved with age. Therefore, the agility test was concluded to be a valid and reliable indicator (Hulse et al., 2012).

505 agility test

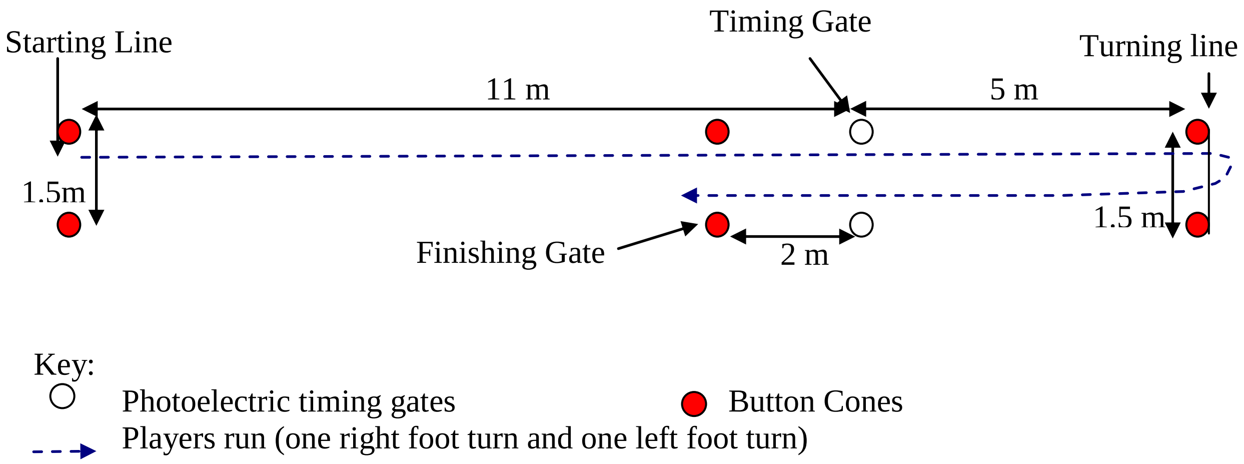


Figure 3.3 Set-up of 505 agility test

Each participant was given 2 practice runs through the course. Participants had to use their right foot to turn in the first practice run and their left foot in the second. The participant stood with their preferred foot on the start line which was 1 metre behind the start timing gate. The participants started the run in their own time and sprinted all the way to the turning line, and then performed 180° turn. After the turn, participant sprinted to the finishing gate. Four valid timed runs were performed in the same order as practices and 2-5 min recovery time was given in between the runs (Balsom et al., 1992). Participants had to put their foot on or over the turning line. If the line was not reached, the run was deemed invalid and then repeated after 2-5 min recovery time.

Squat jump

The participants stood with their feet shoulder width apart on the jump mat. The participants placed both hands on their hips and squatted down to their lowest comfortable position. After stopping in this position for 1-2 s, the participants jumped vertically as high as possible. The participant's 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 participant had to take-off and then land from their toes with straight legs on the jump mat. If any of these points were violated, the jump was deemed invalid and had to be repeated. Each participant performed three valid jumps (The Football Association Medical and Exercise Science Department, 2004).

Counter movement jump without arms

The participants stood with their feet shoulder width apart on the jump mat with both hands on their hips. From this standing position the participants performed a counter movement jump. The participants' hands had to remain on their hips throughout the jump. The participants had to take off and land from their toes with straight legs on the jump mat. If any of these points were violated the jump was deemed invalid and had to be repeated. Each participant performed three valid jumps (The Football Association Medical and Exercise Science Department, 2004).

Counter movement jump with arms

The participants stood with their feet shoulder width apart on the jump mat. From this standing position the participants performed a counter movement jump using their arms to assist them during the jump. The participants had to take-off and then land from their toes with straight legs on the jump mat. If this point was violated the jump was deemed invalid and was then repeated. Each participant performed three valid jumps (The Football Association Medical and Exercise Science Department, 2004).

In a previous validity and reliability study, the U9-U18 English Premier League Academy players (N = 80, age = 13.2 ± 2.6 years) performed a squat jump, counter movement without arms and counter movement jump with arms on two occasions (7 days apart) and the jumps were performed between 17:30 and 19:30. The jump performance differed by less than 1 cm between the two occasions and the coefficient of variation was 4.4 to 6.4% in the U9-U11, U12-U14 and U15-U18 age groups. Moreover, jump performance distinguished between average and above average players classified by coaches and improved with age. Therefore, the standing vertical jump performance was concluded to be a valid and reliable indicator (Hulse et al., 2012).

The Yo-Yo intermittent recovery test (level 1)

The Yo-Yo intermittent recovery test (Bangsbo, 2005) CD was checked by timing the gap between two auditory signals separated by 60 s on the CD. Participants wore heart rate monitors (Polar team system, Polar electro limited) during the test. The test consisted of repeated running of 2 x 20 m back and forth between 2 lines. The timing was notified by audio bleeps from a CD player and the time allowed to complete each run was progressively shortened. The participants had a 10 s active recovery period which consisted of 2 x 5 m jogs in between running bouts. Participants were withdrawn from the test when they failed to reach the finish line in time twice during the test. The distance covered during the test was recorded and used as the test result. Then the heart rate monitors were taken off and data were downloaded into the computer for later analysis.

The reliability of the Yo-Yo intermittent recovery test (level 1) has been previously examined. Thirteen males (age = 28 (range = 25-36) years) took part in the Yo-Yo intermittent recovery test (level 1) twice within a week and no significant difference in the performance (1867 ± 72 m vs. 1880 ± 89 m) was reported with coefficient of variation of 4.9% (Krustrup et al., 2003). Moreover, six to nine year old children (14 boys and 21 girls) participated in a modified Yo-Yo intermittent recovery test (level 1) (distance was 16 m instead of 20 m) twice and there were 2-3 days between the tests. No difference in the test performance was found (693 ± 418 m vs. 670 ± 328 m) and the coefficient of variation was 26% for the 6-7 year olds (6 boys and 12 girls) and 13% for the 8-9 year olds (8 boys and 9 girls) (Ahler et al., 2011). Furthermore, a relationship has been found between the Yo-Yo intermittent recovery test (level 1) performance and high intensity match running performance in elite professional soccer players (N = 37, mean age = 26 years, r = 0.71) (Krustrup et al., 2003) and in elite youth soccer players (N = 21, age = 14.1 ± 0.2 years, r = 0.77) (Castagna et al., 2009), thus illustrating the validity of the Yo-Yo intermittent recovery test (level 1) for match running performance in soccer.

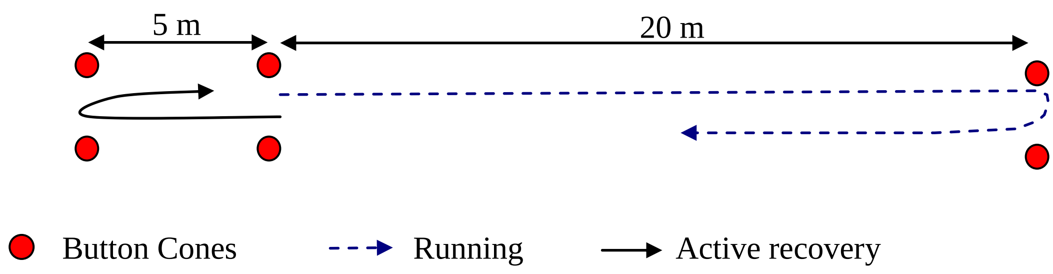


Figure 3.4 Set up of the Yo-Yo intermittent recovery test

The Multi-stage fitness test

The Multi-stage fitness test (Ramsbottom et al., 1988) CD was checked by timing the gap between two auditory signals separated by 60 s on the CD. The test consisted of continuous running between 2 lines which were 20 m apart. The timing of runs was notified by bleeps from a CD player and it was progressively shortened roughly every minute. The test continued until the participants failed to reach the line in time on 3 consecutive occasions. The distance covered during the test was recorded and used as the test result. Participants wore a heart rate monitor (Polar team system, Polar electro limited) during the test and data were downloaded into the computer for later analysis.

The reliability of the Multi-stage fitness test has been previously examined in 188 boys and girls aged 8-19 years. The participants performed the test twice with a week between the tests and no significant differences between the performances was found ($r = 0.89$) (Leger et al., 1988). Moreover, 104 boys and 104 girls aged 11-16 years took part in the Multi-stage fitness test and their peak heart rate within the last 5 s of the test was 196 beats per minute. Compared to the peak heart rates reported in previous literature (Aandstad et al., 2006; Moller et al., 2007), the authors concluded that the Multi-stage fitness test elicits a maximal effort from 11-16 years old children (Voss and Sandercock, 2009). The relationship between the Multi-stage fitness test performance and peak oxygen uptake (Leger et al., 1988) and between the Multi-stage fitness test performance and standard of adult soccer players (Edwards et al., 2003) has been previously examined and authors have concluded that the Multi-stage fitness test is a valid predictor of peak oxygen uptake. However, the Multi-stage fitness test performance has been shown not to distinguish between professional and recreational adult male soccer players (Edwards et al., 2003).

3.2.5 Warm-ups

For sprint and agility tests

All the actions during the warm up were performed while players were moving over 30 m back and forth. The participants performed a 10 min standardised warm up consisted of walking, jogging, cruising, sprinting and dynamic stretches. The participants were given two minutes to prepare themselves after the warm up.

For standing vertical jump tests

Participants performed 5 squats, 5 two foot ankle hops and 5 two foot counter movement jumps in this order before measuring standing vertical jump height.

For the endurance tests

Participants travelled over 30 m back and forth.

1. Participants jogged for 50 s and then walked for 10 s. This sequence was repeated for 2 min.

2. Participants were given 2 min for their own preparation (e.g. stretching and adjustment of footwear).

3.3 Match analysis

Soccer matches were analysed using a GPS (1 Hz, SPI Elite, GPSport, Australia). This system required players to wear a heart rate monitor (T34, Polar Electro Ltd) and small backpack on their back which contained the device; players wore this equipment throughout the match. The matches were played on flat grass pitches; pitch dimensions and duration of the matches are illustrated in table 3.1. The matches were 6-a-side for the U9 and U10 squads and, 11-a-side for the U11-U16 squads. The matches were part of the regular series of inter-academy matches between Premier League Academies during a season. Completion of at least a half of the duration of a match in two separate matches was the criterion for inclusion in the study. Mean values from matches were calculated for each player. The GPS accessed a mean of 7.7 ± 1.4 satellites with a mean horizontal dilution of precision of 1.26 ± 0.29 throughout all the matches analysed.

Table 3.1 Pitch and penalty area dimensions, duration of matches and area per player for the U9-U16 squads.

<table>
<tr><th></th><th>Pitch dimension (m)</th><th>Penalty area (m)</th><th>Duration</th><th>Area per player ($m^2 \cdot plyer^{-1}$)</th></tr>
<tr><td>U9</td><td rowspan="2">44.8 x 26.0</td><td rowspan="2">9.0 x 18.8</td><td rowspan="2">15 min x 4 or (20 min x 2 + 15 min x 2)</td><td rowspan="2">97.1</td></tr>
<tr><td>U10</td></tr>
<tr><td>U11</td><td rowspan="2">78.7 x 54.1</td><td rowspan="2">14.7 x 36.6</td><td>(20 min x 2 + 15 min x 2) or 25 min x 3</td><td rowspan="2">193.5</td></tr>
<tr><td>U12</td><td rowspan="2">25 min x 3</td></tr>
<tr><td>U13</td><td>88.0 x 64.2</td><td rowspan="2">16.5 x 40.32</td><td>256.8</td></tr>
<tr><td>U14-U16</td><td>100.8 x 68.2</td><td>40 min x 2</td><td>312.5</td></tr>
</table>

<u>3.3.1 Validity</u>

The validity of GPS (1 Hz, SPI elite, GPSport, Australia) has been previously examined using a circuit (487 m). Male and female adult games players (N = 9) completed 14 laps in a trial and the circuit involved moving at different speeds including walking to sprinting and various agility runs (8.5-52.3 m). The actual distance covered by the participants in the trial (6818.0 m) and the total distance measured by the devices only differed by 2.5 m and there was less than a 1% difference in the actual distance covered and the distance measured by the devices during agility runs. The mean speed during different agility runs ranged from 1.5 to

3.6 $m \cdot s^{-1}$ (MacLeod et al., 2009). In contrast, Duffield and colleagues (2010) reported that compared to a 22 camera VICON motion analysis system (100Hz, Oxford Metrics, UK), 1 Hz GPS (1 Hz, SPI elite, GPSport, Australia) can underestimate the distance by up to around 40% if a movement is repeated (over 4 m and 8 m) in confined spaces (mean speed = 0.8-1.4 $m \cdot s^{-1}$, peak speed = 1.9-2.7 $m \cdot s^{-1}$). However, it is questionable whether the video system utilised was a suitable gold standard to compare the 1 Hz system against and no actual measurements of distances were made. Thus, overall, these studies showed that the 1 Hz GPS has acceptable validity (MacLeod et al., 2009; Gray et al. 2010) up to speeds of 3.6 $m \cdot s^{-1}$ except possibly where movements are repeated in very confined areas (Duffield et al., 2010). However, it is encouraging that the MacLeod study (MacLeod et al. 2009) attempted to replicate the movement patterns observed in field hockey, which has a similar movement pattern to soccer, and found very acceptable validity at the speeds and patterns of movement tested. At higher speeds, however, above 4 $m \cdot s^{-1}$ which do occur in soccer, some poor validity has been observed in earlier studies. When University physical education students sprinted over 15 and 30 m in a straight line, the correlation between peak speed assessed by GPS (1 Hz, SPI elite, GPSport, Australia) and sprint time over 15 m ($r = 0.87$) was lower than that between GPS peak speed assessment and sprint time over 30 m ($r = 0.94$) (Barvero-Alvarez et al., 2010). Thus, although there are some methodological limitations with the published studies, it seems the 1 Hz GPS may underestimate (only one study has shown a slight overestimate) distances covered when the speed is fast (> 4.0 $m \cdot s^{-1}$) and particularly during the acceleration phase.

3.3.2 Reliability

The reliability of a 1 Hz GPS (SPI elite, GPSport, Australia) has been previously examined and included a 128.5 m circuit with change of directions at different angles and movements with different speed (walking, jogging, fast running and sprinting). Participants wore a harness with two GPS devices and completed 6 laps during a trial with a minute to complete a lap and there was a 5-15s recovery time in between the laps. The coefficients of variation were 4 and 3.6% for the lap and bout (6 laps), respectively. However, coefficient of variation during running at > 20 $km \cdot h^{-1}$, > 14.4 $km \cdot h^{-1}$ and < 14.4 $km \cdot h^{-1}$ were 15.4, 11.2 and 4.3%, respectively (Coutts and Duffield, 2010). Therefore, 1 Hz GPS has an acceptable inter-model reliability for estimating long distances covered, for example during the course of a match.

However, the reliability declines when short distances are covered at high speeds or during acceleration.

3.4 Match activities

Speed zones specific to each age group were calculated and six speed zones (walking, jogging, low speed running, moderate speed running, high speed running and sprinting) were generated. A running speed faster than two standard deviations below their age group estimated sprint speed at 7.5 m was considered as sprinting. The other 5 speed categories were calculated by dividing the speed zones of 0.0 $m \cdot s^{-1}$ to the minimum sprinting speed into 5 equal categories. The speed zones employed for each squad are listed in table 3. The distances covered by the six locomotor categories were estimated using Team AMS software version 1.2 (GPSport, Australia) and they were presented in $m \cdot h^{-1}$. Also, the percentage time spent in each zone during a match, was calculated. In Chapter 6 and 8, only the match running performance variables related to high intensity activities (total distance covered and, moderate and high speed running performances) were included in the analysis as it has been reported that high intensity activities are more important in distinguishing the standard of soccer players (Bangsbo et al., 1991; Mohr et al., 2003).

Table 3.2 The speed zones for match analyses of the U9-U16 squads presented in $m \cdot s^{-1}$.

	U9	U10	U11	U12	U13	U14	U15 and U16
Standing and walking	0.0 - 1.0	0.0 - 1.0	0.0 - 1.1	0.0 - 1.1	0.0 - 1.1	0.0 - 1.2	0.0 - 1.2
Jogging	1.1 - 2.0	1.1 - 2.1	1.2 - 2.1	1.2 - 2.2	1.2 - 2.2	1.1 - 2.3	1.3 - 2.4
Low speed running	2.1 - 3.1	2.2 - 3.1	2.2 - 3.2	2.3 - 3.2	2.3 - 3.3	2.4 - 3.5	2.5 - 3.7
Moderate speed running	3.2 - 4.1	3.2 - 4.2	3.3 - 4.2	3.3 - 4.3	3.4 - 4.4	3.6 - 4.6	3.8 - 4.9
High speed running	> 4.1	> 4.2	> 4.2	> 4.3	> 4.4	> 4.6	> 4.9

3.5 Statistical analysis

Statistical tests were conducted when there were at least five participants. One way analysis of variance with Tukey post hoc test was used to compare three or more groups and independent sample t-test was used when there were 2 groups. Kolmogorov-Smirnov test was employed to test distribution of normality and homogeneity of variance was examined using Levene's test. Instead of using independent sample t-test, the Wilcoxon Signed Ranks test was used when the samples were not normally distributed. Results are presented as mean ± standard deviation (SD) and PASW 18.0 was used for all the statistical analyses. In tables, stage of genital development and stage of pubic hair development are expressed as G and PH, respectively (e.g., stage 3 of genital development = G3). Goalkeepers were excluded from all statistical analysis and data presented.

Chapter 4

Physical characteristics of elite youth soccer players – cross sectional analysis

4.1 Introduction

There has been a large amount of research conducted recently aiming to elucidate the physical characteristics of elite senior soccer players (Clark et al., 2008; Cometti et al., 2001; Dunbar and Power, 1997; Edwards et al., 2003; Impellizzeri et al., 2006; Krustrup et al., 2003; Puga et al., 1993; Rampinini et al., 2007a; Rienzi et al., 2000; Wisloff et al., 2004; Zerguini et al., 2007). However, there have been very few investigations of elite youth soccer players, especially when the players are sub-divided into different age groups (Castagna et al., 2009; Chamari et al., 2004; Hulse, 2010, unpublished; McMillan et al., 2005b; Reilly et al., 2000; Stroyer et al., 2004). Knowledge concerning the physical profile of elite youth players would be beneficial in talent identification, that is in terms of predicting which players might move on to a higher playing level and also in terms of developing the scientific knowledge relating to how young elite athletes progress and develop over time. The physical characteristics and physical performance of elite youth soccer players might be expected to develop in a different way to the sedentary population as two previous studies have shown that soccer players are early maturers (Baxter-Jones and Helms, 1996; Malina et al., 2000) and possess a date of birth in the first half of the year (Carling 2009). Moreover, participation in a regular intensive training may influence the development of physical characteristics and physical performance in children and adolescence although this is an area of controversy (Jones and Helms, 1993).

The players commonly recruited in earlier studies examining the physical profile of soccer players had a chronological age range of 12-18 years, highlighting the lack of information regarding pre-pubertal age groups (Chamari et al., 2005; Helgerud et al., 2001; Malina et al., 2007; Reilly et al., 2000; Stroyer et al., 2004; Vaeyens et al., 2006). Moreover, in most of the earlier studies only a very limited range of physical characteristics (e.g., standing height) and physical performance (e.g., sprint performance) were assessed. Therefore, it would add substantially to the literature if the physical characteristics and physical performance profile of a wide age range of players (e.g., 9-18 years) across a wide range of physical characteristics (e.g., standing height, body mass, estimated body fat) and physical performance (e.g., sprint, agility, power, endurance) could be assessed.

The Premier League Academy System was established in 1998 and aimed to develop the best available talented players to their full potential to produce high quality professional players. Squads in Premier League Academy start from the U9 and continue, unless released, up to the U18. There is a squad in each of the younger age groups while the U15 and U16 age groups are combined to form one squad and the U17 and U18 age groups form another. There are currently 41 English professional clubs operating a Premier League Academy and all of the Premier league clubs are members of the Academy (http://www.premierleague.com/page/AcademicsPL/0,,12306~1078162,00.html). Previously a study of Premier League Academy players (N = 954, chronological age = 16.3 ± 1.6 years) examined standing height, body mass, 20 m sprint time with a split time at 10 m, Slalom agility test, 3 different types of standing vertical jumps and a sub-maximal Multi-stage fitness test. The players were separated into professional graduates (players who went on to gain a professional contract) and non-professional graduates (players who failed to gain a professional contract). When the physical characteristics and physical performance of the two groups were compared, the professional graduates were significantly taller and heavier, were significantly faster in sprint and agility tests and jumped significantly higher in three standing vertical jumps compared to non-professional graduates. Therefore, standing height, body mass, speed, agility and jump height are predictors of players who might go on to sign a professional contract (Hulse, 2010, unpublished) and it would be of value therefore to include these measures, and others in future studies.

In the current study reported in this chapter and throughout the thesis, participants were recruited from an English Premier League Academy based in the East Midlands and represented all age groups. Measurements taken in the study reported in this chapter included standing height, body mass, sum of 4 skinfold sites, 30 m sprint times with split times at 5, 10, 15 and 20 m, 2 agility tests, 3 different types of standing vertical jumps and 2 maximal endurance tests. The present study sought to develop and extend the work of Hulse (2010, unpublished) by including estimated body fat, 5, 15 and 30 m sprint times, 505 agility test and 2 tests of endurance to increase the range of measurements on elite youth soccer players. It was hypothesised that: the changes in physical characteristics and physical performance (cross sectional data) would be the greatest around the age of 11-13 years reflecting the expected earlier maturation of elite soccer players and; that the physical characteristics and physical performance of elite players will be enhanced in comparison with the normal population at the same chronological age.

4.2 Methods

4.2.1 Participants

The participants were 183 Premier League Academy players from a club in East Midlands and their chronological age ranged from 8.9 to 18.7 years. The U9-U14 squads had 3 training sessions a week, the U15 and U16 squads had 4 training sessions a week and, the U17 and U18 squads had 6 training sessions a week. All squads had an average of 1 match per week during a season. Players were provided with a written and verbal explanation of the study including all tests and measurements to be taken. Each player signed an informed consent form and completed a health screen questionnaire prior to participation in the study. Where players were under 18 years old players' parents, guardians or care-givers signed the consent form prior to the start of the study. Participants were withdrawn from a particular test if they did not have a satisfactory health status. The study was approved by Loughborough University Ethical Committee.

4.2.2 Measurements

Measurements were taken in May 2008, 2009 and 2010. Of the 183 participants, 137 were tested once only, 38 were tested twice and 8 were tested on three occasions. Testing was undertaken during two 2-3 hour sessions on 2 separate days, within a 3 day period. A series of measurements were made: standing height, body mass, skinfolds, 30 m sprint with split times at 5, 10, 15 and 20 m, Slalom agility test, modified 505 agility test (Draper and Lancaster, 1985), squat jump, counter movement jump without arms, counter movement jump with arms, the Yo-Yo intermittent recovery test level 1 (Bangsbo, 2005), and the Multi-stage fitness test (Ramsbottom et al., 1988). All the performance tests were separated by 3-5 min and only one endurance test was conducted in each session. The endurance test was always the last test to be conducted. Players were asked to perform maximally in all the performance tests. Details of each measurement can be seen in Chapter 3.

4.2.3 Statistical analyses

Differences between squads or age groups were analysed using one way analysis of variance (ANOVA) with Tukey post hoc test and the level of statistical significance was set at $p < 0.05$. Results are presented as mean ± standard deviation (SD) and PASW 18.0 was used for all the statistical analyses. Goalkeepers were excluded from all statistical analysis and data presented.

4.3. Results

4.3.1 Anthropometry

Standing height

Mean standing height (SD) ranged from 139.4 (4.8) cm for the U9 squad to 181.3 (5.6) cm for the U17 squad ($p < 0.01$). Height increased with chronological age until age 17 (figure 4.1), but there was no significant difference in standing height between the U15-U18 squads.

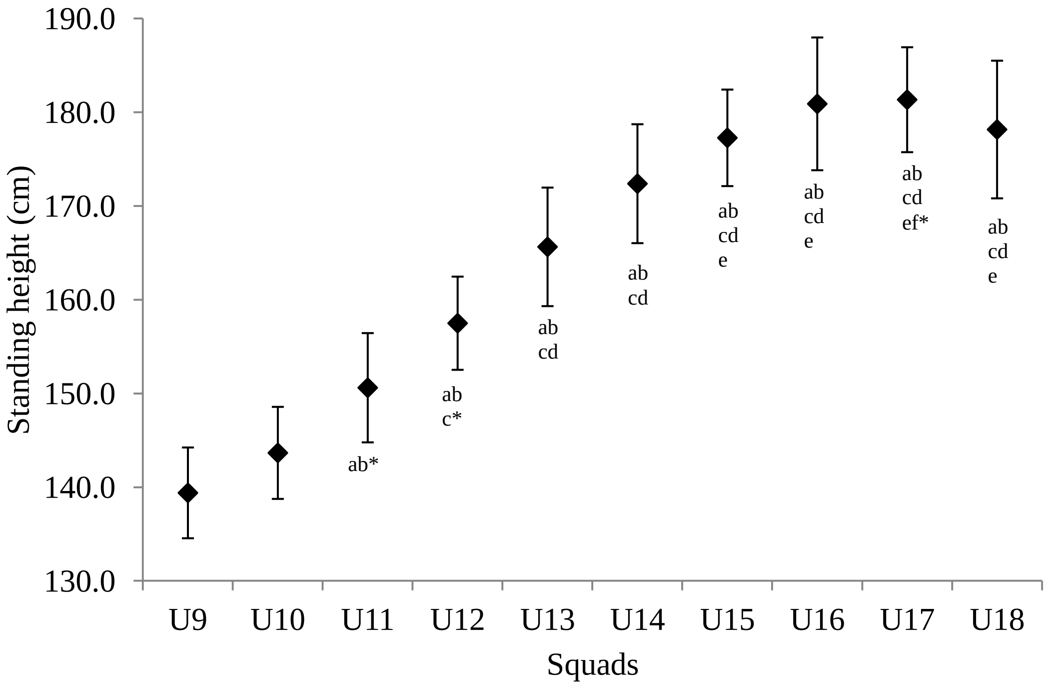


Figure 4.1 Standing height (mean ± SD) of each squad. a = $p < 0.01$ vs. U9, b = $p < 0.01$ vs. U10, c = $p < 0.01$ vs. U11, d = $p < 0.01$ vs. U12, e = $p < 0.01$ vs. U13, f = $p < 0.01$ vs. U14. *$p < 0.05$.

Body mass

Body mass (mean ± SD) increased from the U9 squad (33.6 ± 3.9 kg) to the U17 squad (72.6 ± 5.7 kg) as the players aged ($p < 0.01$). However, there was no significant difference in body mass between the U15-U18 squads (figure 4.2).

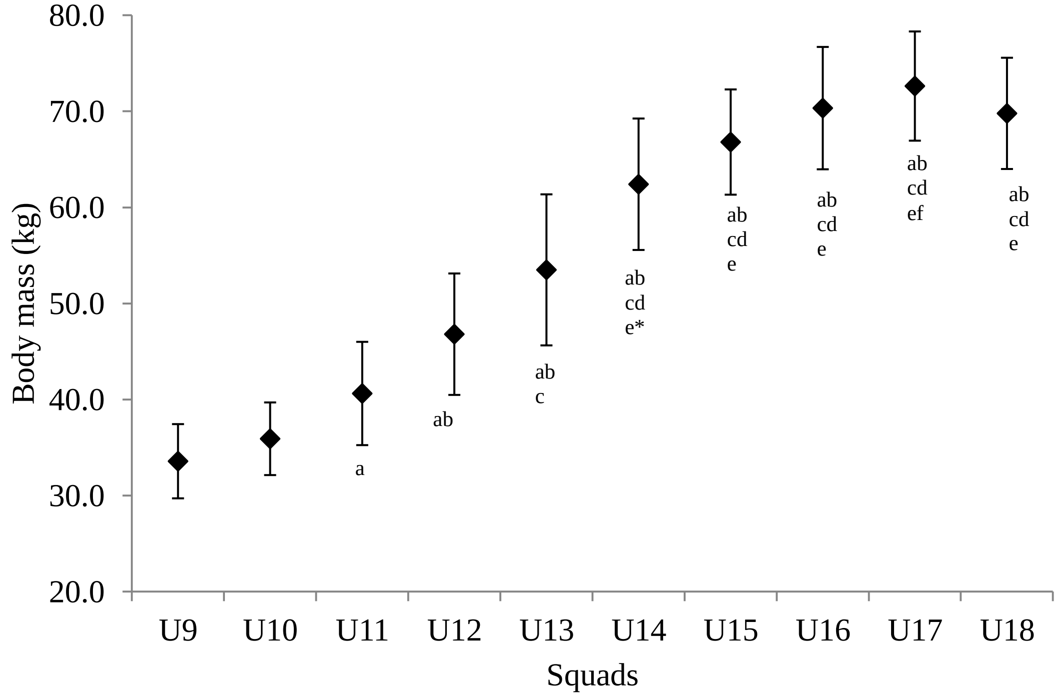


Figure 4.2 Body mass (mean ± SD) of each squad. a = p < 0.01 vs. U9, b = p < 0.01 vs. U10, c = p < 0.01 vs. U11, d = p < 0.01 vs. U12, e = p < 0.01 vs. U13, f = p < 0.01 vs. U14. *p < 0.05.

<u>Sum of 4 skinfold sites and estimated body fat composition</u>

The squad mean of sum of 4 skinfold sites (SD) ranged from 27.3 (5.7) mm (U13 squad) to 31.9 (7.4) mm (U15 squad) and there was no significant difference in the sum of 4 skinfold sites (table 4.1). Estimated body fat composition ranged from 11.6% (U16 squad) to 16.3% (U11 squad) and a significant difference was found only between the U10 (14.9 ± 2.9%) and U16 (11.6 ± 2.8%) squads (table 4.1).

Table 4.1 Number of participants, chronological age, sum of 4 skinfold sites and estimated body fat composition from each squad.

	N	Chronological age (years)		Sum of 4 skinfold sites (mm)		Estimated body fat composition (%)	
		Mean	SD	Mean	SD	Mean	SD
U9	27	9.4	0.3	27.9	9.5	14.6	3.9
U10	23	10.4	0.2	28.5	7.3	14.9	2.9
U11	16	11.4	0.2	31.8	11.2	16.3	4.8
U12	18	12.4	0.3	30.4	10.4	13.6	3.9
U13	22	13.4	0.3	27.3	5.7	12.6	3.3
U14	12	14.4	0.2	27.6	6.5	12.4	3.7
U15	16	15.4	0.2	31.9	7.4	12.4	3.2
U16	15	16.3	0.3	30.3	6.2	11.6[b]	2.8
U17	21	17.3	0.3	29.7	6.9	11.9	3.2
U18	13	18.4	0.2	31.5	7.9	11.9	3.1

b = $p < 0.01$ vs. U10.

4.3.2 Sprints

<u>5 m</u>

There was an improvement in sprint time to cover 5 m as players aged from the U9 (1.15 ± 0.04 s) to U15 (0.99 ± 0.04 s) squads ($p < 0.01$). There was no significant difference between the U15-U18 squads and the fastest mean sprint time of a squad was 0.98 s in the U17 squad (figure 4.3).

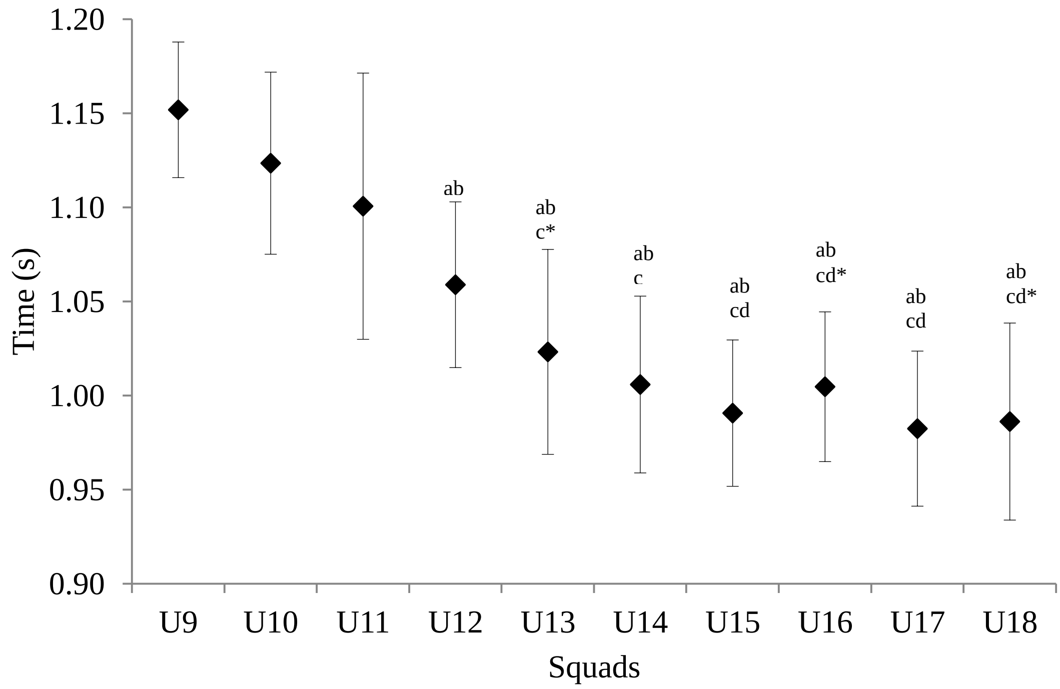


Figure 4.3 Squads and 5 m sprint time (mean ± SD). a = p < 0.01 vs. U9, b = p < 0.01 vs. U10, c = p < 0.01 vs. U11, d = p < 0.01 vs. U12. *p < 0.05.

<u>10 m</u>

Ten metre sprint time improved with chronological age until age 17 (1.71 ± 0.05 s) from the U9 squad (2.03 ± 0.07 s) but the improvement was not consistent (Table 4.2). There were no significant differences in sprint time over 10 m between the U14-U18 squads, but only the U17 squad was significantly faster than the U13 squad ($p < 0.01$).

<u>15 m</u>

An improvement in 15 m sprint time was seen with chronological age up to the U17 squad ($p < 0.01$) and the fastest and slowest squad mean times of 15 m sprint were 2.36 s (U17 and U18 squads) and 2.85 s (U9 squad), respectively (figure 4.4). There was no significant difference in 15 m sprint time between the U14–U18 squads. However, the U16-U18 squads were significantly faster than the U13 squad.

<u>20 m</u>

Sprint time over 20 m ranged from 3.65 ± 0.14 s (U9 squad) to 2.96 ± 0.08 s (U17 squad). There was an improvement in sprint time to cover 20 m with age until age 17 ($p < 0.01$).

There were no significant differences in 20 m sprint time between the U14-U18 squads (table 4.2).

<u>30 m</u>

The 30 m sprint time improved with chronological age until age 17 ($p < 0.01$). The fastest squad mean time was 4.15 ± 0.11 s shown by the U17 squad and the slowest squad mean time was 5.26 ± 0.25 s demonstrated by the U9 squad (figure 4.4). No significant difference in 30 m sprint time was found between the U14-U18 squads.

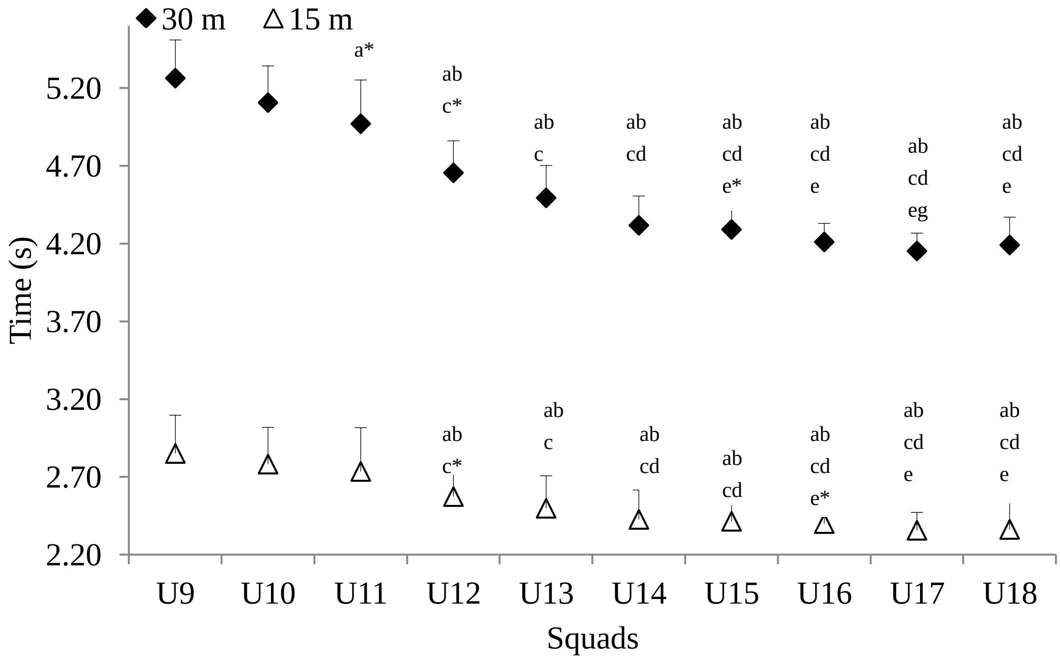


Figure 4.4 Chronological age, 15 and 30 m sprint time (mean ± SD) for each squad.
a = $p < 0.01$ vs. U9, b = $p < 0.01$ vs. U10, c = $p < 0.01$ vs. U11, d = $p < 0.01$ vs. U12, e = $p < 0.01$ vs. U13, g = $p < 0.01$ vs. U15. *$p < 0.05$.

Table 4.2 Number of participants, chronological age, sprint time at 10 and 20 m from each squad.

Chronological age (years)		Sprints (s)			
		10m		20m	
Mean	SD	Mean	SD	Mean	SD
9.4	0.3	2.03	0.07	3.65	0.14
10.4	0.2	1.99	0.07	3.56	0.15
11.4	0.2	1.95	0.10	3.48	0.19
12.4	0.3	1.85[ab]	0.07	3.27[abc*]	0.13
13.4	0.3	1.80[abc]	0.08	3.17[abc]	0.14
14.4	0.2	1.75[abcd*]	0.07	3.05[abcd]	0.12
15.4	0.2	1.74[abcd]	0.05	3.05[abcd]	0.09
16.3	0.3	1.74[abcd]	0.06	3.02[abcde]	0.08
17.3	0.3	1.71[abcde]	0.05	2.96[abcde]	0.08
18.4	0.2	1.72[abcd]	0.06	2.97[abcde]	0.09

a = p < 0.01 vs. U9, b = p < 0.01 vs. U10, c = p < 0.01 vs. U11, d = p < 0.01 vs. U12, e = p < 0.01 vs. U13, g = p < 0.01 vs. U15. *p < 0.05.

4.3.3 Agility tests

Slalom agility test

In the Slalom agility test, completion time improved with chronological age until age 17 ($p < 0.01$) and the time ranged from 4.83 ± 0.25 s (U9 squad) to 3.96 ± 0.09 s (U17 squad). There was no significant difference between the U15-U18 squad that only the U17 squad was significantly faster than the U14 squad (figure 4.5).

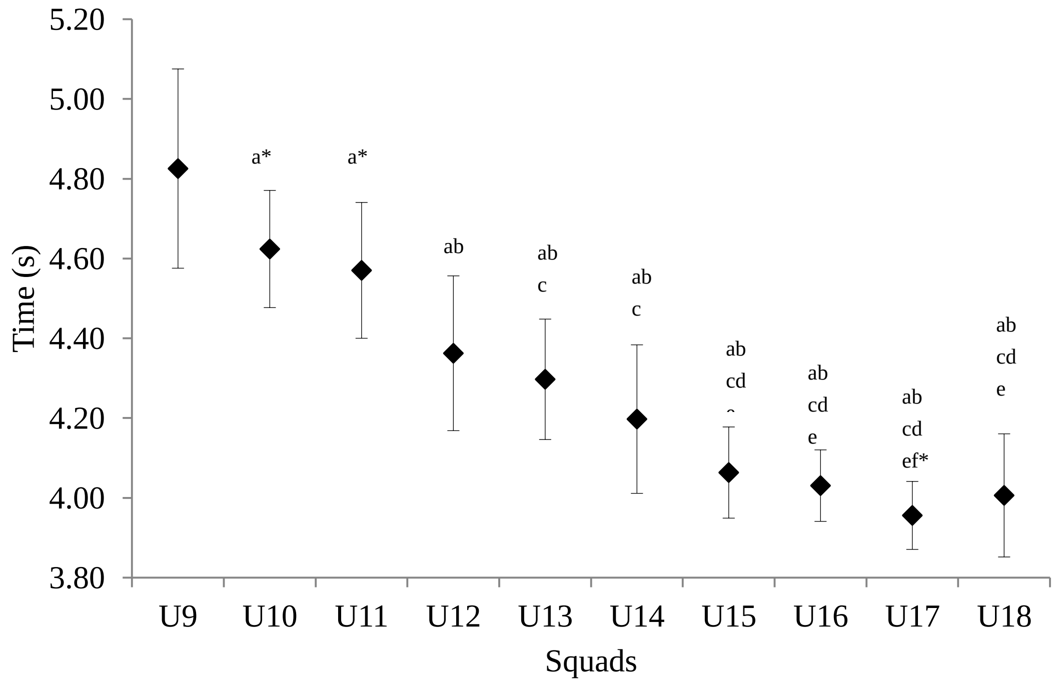


Figure 4.5 Chronological age and Slalom agility test completion time (mean ± SD) of each squad. a = $p < 0.01$ vs. U9, b = $p < 0.01$ vs. U10, c = $p < 0.01$ vs. U11, d = $p < 0.01$ vs. U12, e = $p < 0.01$ vs. U13, f = $p < 0.01$ vs. U14. *$p < 0.05$.

505 agility test

The fastest and slowest squad mean times were 2.27 s (U17 squad) and 2.67 s (U9 squad), respectively (figure 4.6). There was a clear improvement in the completion time from the U9 squad (2.67 ± 0.11 s) to the U17 squad (2.27 ± 0.07 s, $p < 0.01$), but no significant difference was found between the U16-U18 squads.

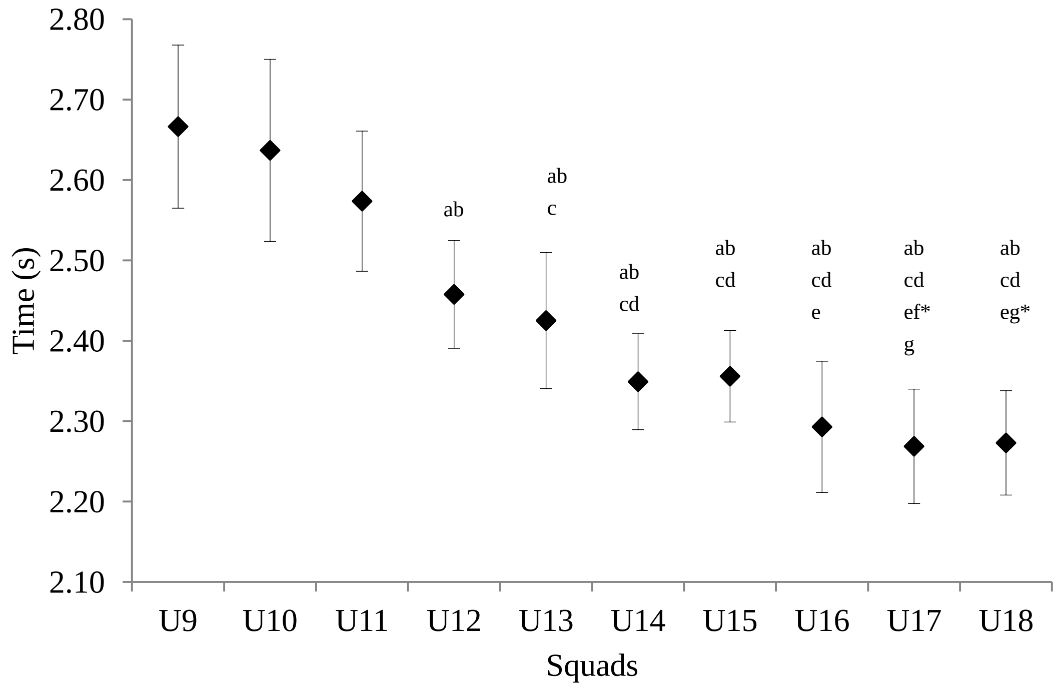


Figure 4.6 Chronological age and 505 agility test completion time (mean ± SD) of each squad. a = $p < 0.01$ vs. U9, b = $p < 0.01$ vs. U10, c = $p < 0.01$ vs. U11, d = $p < 0.01$ vs. U12, e = $p < 0.01$ vs. U13, f = $p < 0.01$ vs. U14, g = $p < 0.01$ vs. U15. *$p < 0.05$.

4.3.4 Standing vertical jump height

Squat jump

Jump performance of squat jump ranged from 26 ± 3 cm (U9 squad) to 39 ± 4 cm (U16 and U17 squads) and an increase in squat jump performance was observed as the players aged until age 17 ($p < 0.01$). There was no significant difference in squat jump performance between the U14-U18 squads (table 4.3).

Counter movement jump without arms

Performance during the counter movement jump without arms ranged from 26 ± 4 cm for the U9 squad to 41 ± 3 cm and 41 ± 5 cm for the U16 and U18 squads, respectively. The performance of the counter movement jump without arms increased with chronological age until age 16 ($p < 0.01$) and there was no difference in the score between the U14-U18 squads (figures 4.7).

Counter movement jump with arms

There was an improvement in performance of counter movement jump with arms from the U9 to U17 squads ($p < 0.01$) and the lowest and highest jump heights were 30 ± 3 cm (U9 squad) and 48 ± 6 cm (U17 squad). No significant difference in the counter movement jump with arms was found between the U14-U18 squads, although only the U16 ($p < 0.05$) and U17 ($p < 0.01$) squad showed a significantly better performance of counter movement jump with arms than the U13 squad (figure 4.7).

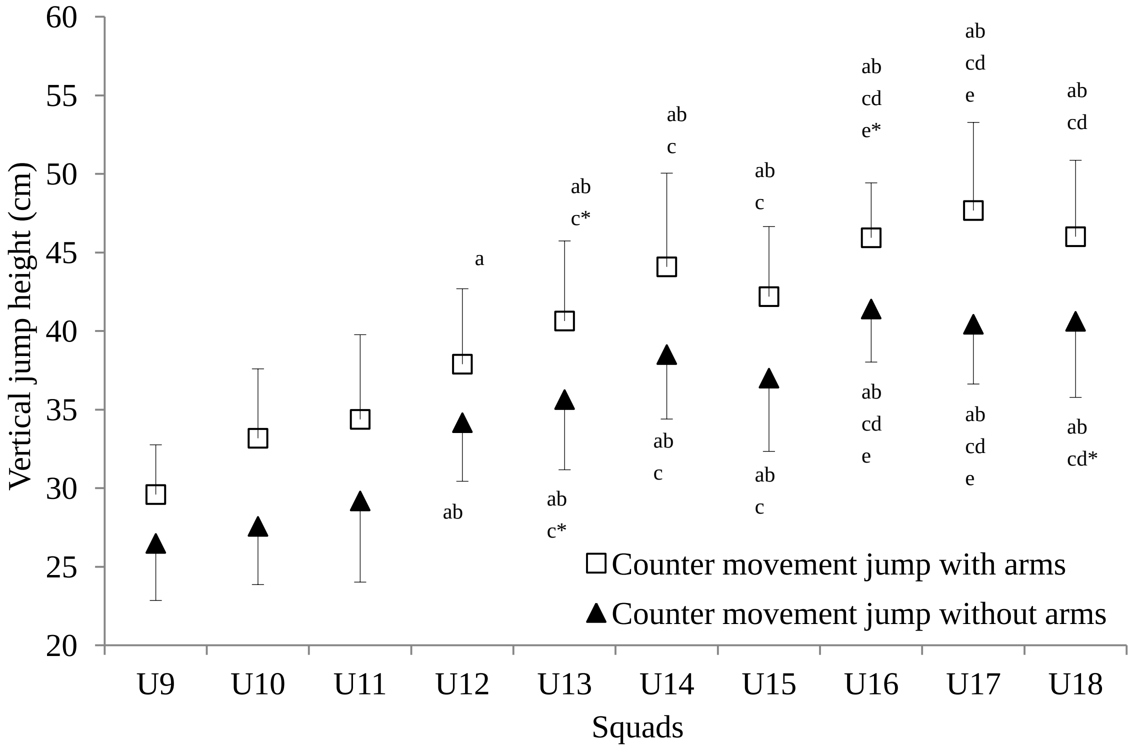


Figure 4.7 Chronological age and scores from counter movement jump with and without arms (mean ± SD) of each squad. a = $p < 0.01$ vs. U9, b = $p < 0.01$ vs. U10, c = $p < 0.01$ vs. U11, d = $p < 0.01$ vs. U12, e = $p < 0.01$ vs. U13. *$p < 0.05$.

4.3.5 Endurance tests

Yo-Yo intermittent recovery test (level 1)

Overall, an increase in performance during the Yo-Yo intermittent recovery test (level 1) was seen with increase in chronological age until age 17 ($p < 0.01$, figure 4.8). The distance covered increased from the U9 squad (787 ± 333 m) to the U17 squad (2617 ± 573 m). There were no significant differences in distance covered during the test between the U17 and the U18 (2760 ± 557 m) squads.

Multi-stage fitness test

An increase in the Multi-stage fitness test performance with chronological age was shown from chronological age 9 until age 17 ($p < 0.01$). The greatest distance covered during the Multi-stage fitness test was 2311 ± 135 m for the U17 squad and the shortest distance covered was 1413 ± 299 m from the U9 squad (figure 4.9). There were no differences in the Multi-stage fitness test performance between the U17 and U18 (2300 ± 218 m) squads.

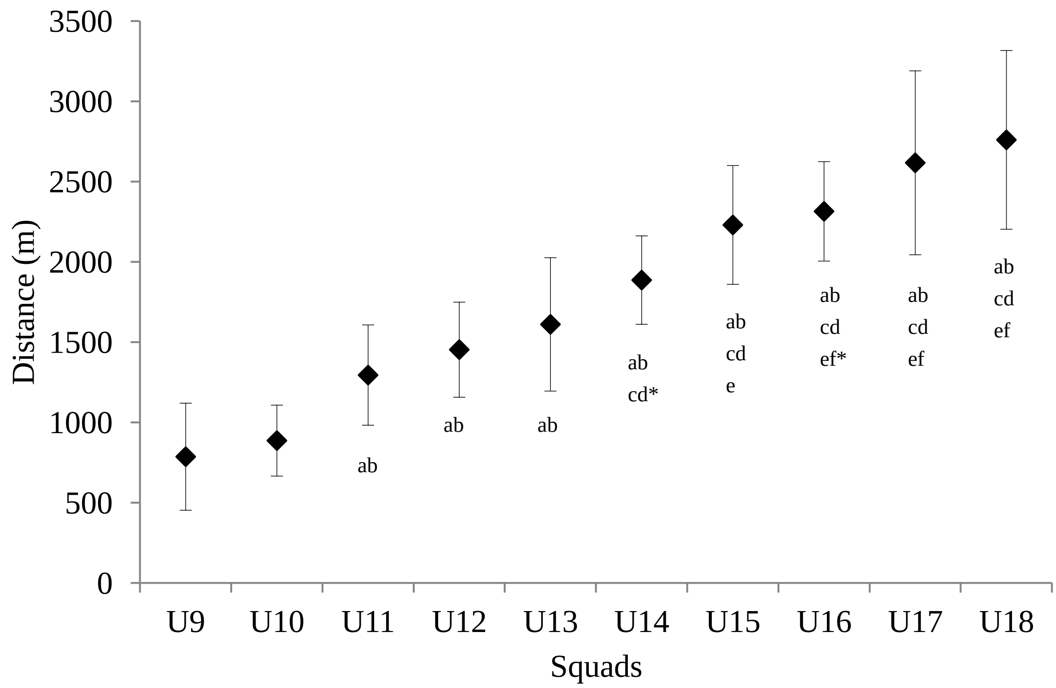


Figure 4.8 Performance in metres (mean ± SD) during the Yo-Yo intermittent recovery test level 1 from each squad. a = $p < 0.01$ vs. U9, b = $p < 0.01$ vs. U10, c = $p < 0.01$ vs. U11, d = $p < 0.01$ vs. U12, e = $p < 0.01$ vs. U13, f = $p < 0.01$ vs. U14. *$p < 0.05$.

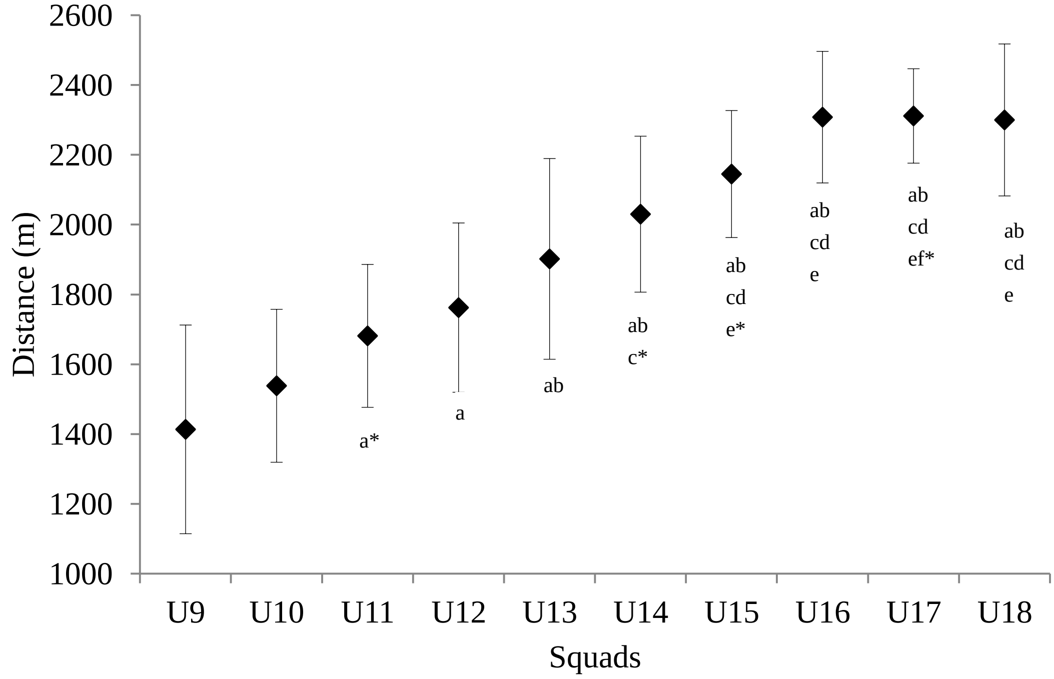


Figure 4.9 Performance in metres (mean ± SD) during the Multi-stage fitness test from each squad. a = $p < 0.01$ vs. U9, b = $p < 0.01$ vs. U10, c = $p < 0.01$ vs. U11, d = $p < 0.01$ vs. U12, e = $p < 0.01$ vs. U13, f = $p < 0.01$ vs. U14. *$p < 0.05$.

Table 4.3 Number of participants, chronological age, squat jump performance and estimated oxygen uptake from each squad.

	N	Chronological age (years)		Squat jump (cm)		Estimated peak oxygen uptake (ml·kg^{-1}·min^{-1})	
		Mean	SD	Mean	SD	Mean	SD
U9	27	9.4	0.3	26	3	43.3	5.0
U10	23	10.4	0.2	27	3	45.4	3.6
U11	16	11.4	0.2	29	5	47.7	3.2
U12	18	12.4	0.3	32	4	48.9	3.7
U13	22	13.4	0.3	34	4	51.0	4.2
U14	12	14.4	0.2	37	5	52.9	3.2
U15	16	15.4	0.2	36	4	54.6	2.6
U16	15	16.3	0.3	39	4	56.9	2.6
U17	21	17.3	0.3	39	4	56.9	1.9
U18	13	18.4	0.2	38	5	56.8	3.0

4.4 Discussion

The key findings of the present study were that all physical and performance variables measured in the study developed over time with chronological age except for the sum of 4 skinfold sites and estimated body fat composition. There was a difference in the duration of development between different physical characteristics. Most of the physical characteristics and performance of some field tests continued developing until the players reached the U17 squad (standing height; body mass; 10, 15, and 30 m sprint times; performance from both agility tests; performance of squat jump and counter movement jump with arms; performance from the Yo-Yo intermittent recovery test (level 1) and Multi-stage fitness test) and the rest of the performance test results stopped developing when the players reached the U15 (5 m sprint) or U16 (20 m sprint; performance from counter movement jump without arms) squad.

The standing height of most squads in the current study showed general agreement with the previous studies (table 2.6, Chapter 2). However, there were differences in standing height between the players from the current study and the players from Belgium (Vaeyens et al., 2006), Croatia (Jankovic et al., 1993) and the English Premier League Academies (Hulse, 2010, unpublished). For example, the U13 age group from the current study (165.6 ± 6.3 cm) were taller than the elite youth soccer players from Belgium (157.7 ± 8.4 cm) and the English Premier League Academies (157.6 ± 8.7 cm). This is possibly because of the differences in player selection criteria between the clubs from the current study and the previous studies. This is an interesting finding as both the current study and a previous study (Hulse, 2010, unpublished) recruited the players from the Premier League Academy. The club from the current study may have a unique player selection criterion within the Premier League Academy clubs as the previous study (Hulse, 2010, unpublished) recruited the players from several clubs opposed to one club in the current study. However, standing height of the U13, U15 and U16 squads from the current study was similar to elite youth soccer players from Australia (Tumilty, 1993), Brazil (Dezan et al, 2004), France (Le Gall et al., 2010), Nigeria (Chibane et al., 2004) and Portugal (Capela et al., 2004a) so the player selection criteria of the club from the current study may be similar to other clubs in the world in term of standing height.

Standing height developed with chronological age until the age of 17. However, the rate of development in standing height was the highest between the U12 and U13 squads and a higher rate of development in standing height was shown between the U9 and U12 squads than between the U13 and U18 squads. This shows that development was greater when the players were younger. This was expected as peak height velocity (PHV) has been reported to occur between 13.8 and 14.2 years of chronological age in general in European boys (Malina et al., 2004a) and PHV for Premier League Academy players has been shown to occur earlier (13.7 years) than the general population (Hulse, 2010, unpublished).

The body mass of the U9-U18 elite youth soccer players recruited in the current study was similar to counterparts from different countries (table 2.6, Chapter 2). However, some of the squads from the current study were heavier than the players from the highest two leagues in Belgium (Vaeyens et al., 2006), prospective international players from Croatia (Jankovic et al., 1993) and the English Premier League Academy players (Hulse, 2010, unpublished). For example, the body mass of the U15 age group from the current study and the Belgian study (Vaeyens et al., 2006) was 66.8 ± 5.5 kg and 57.9 ± 8.2 kg, respectively and the body mass of the U16 age group from the current study and the Croatian study (Jankovic et al., 1993) was 70.3 ± 6.4 kg and 66.2 ± 5.6 kg, respectively. As discussed above, there is possibly a difference in player selection criteria between the clubs recruited in the current study and the previous studies in terms of body size.

Body mass developed gradually with chronological age until the age of 17 in the current study. However, the rate of development in body mass was the highest between the U13 and U14 squads followed by between the U9 and U13 squads and the least development in body mass was shown after reaching the U14 age group. Thus, the development in body mass was larger during the pubescent rather than the prepubescent and postpubescent period which was expected because the chronological age at peak body mass velocity of 232 European youth soccer players has been reported to be 13.8 ± 0.8 years (Philippaerts et al., 2006). It may be that the player selection criteria in a particular club can influence the size of the players selected for that club. Therefore, in the present study which drew participants from one club only, it may be that physical size was influenced in this way. However, the club did not cite body size as a selection criterion when discussing selection with research staff and stated that selection was based only on speed, personality, intelligence and technique (SPIT) consistent with other English Premier League Academies.

There were no significant differences in sum of 4 skinfold sites and estimated body fat composition between the U9-U18 squads except between the U10 and U16 squads in estimated body fat composition. The results from other studies examining estimated body fat composition of elite youth soccer players are shown in literature review (table 2.7, Chapter 2). The players from the current study possessed a similar estimated body fat composition with the counterparts from England (Reilly et al., 2000), France (Le Gall et al., 2010) and Tunisia (Chamari et al., 2005).

Sprint times at 5, 10, 15, 20 and 30 m of the U9 to U18 squads from the current study were compared to those from the elite youth soccer players from different countries (table 2.8, Chapter 2). In general, the sprint times of the elite youth soccer players from the current study were similar to counterparts from Australia (Tumilty, 1993), Belgium (Vaeyens et al., 2006) and the English Premier League Academies (Hulse, 2010, unpublished). However, some squads from the current study seemed to be faster over 10 and 30 m than the counterparts from France (Le Gall et al., 2010; Taiana et al., 1993), Norway (Helgerud et al., 2001), Scotland (McMillan et al., 2005b) and Tunisia (Chamari et al., 2004). For example, the 10 m sprint times of the U13 players from the current study and France (became international players; Le Gall et al., 2010) were 1.80 ± 0.08 s and 1.96 ± 0.10 s, respectively and the 30 m sprint time of the U17 players from the current study and Tunisia (Chamari et al., 2004) were 4.15 ± 0.11 s and 4.38 ± 0.18 s, respectively. There seems to be a slight variation in sprint times between the players from different countries. This is possibly due to differences in player selection criteria because of varying preferences in the tactical approaches in different countries resulting in more or less emphasis on the quality of speed.

All sprint times improved with chronological age until the players reached the U15 (5 m), U16 (20 m) or U17 (10, 15 and 30 m) squad. However, the largest improvement in sprint time occurred between the U10 and U13 squads for 5 and 10 m sprint and between the U11 and U12 squads for the 15, 20 and 30 m sprints. This finding is in line with Belgian boys (Beunen et al., 1988), the English Premier League Academy players (Hulse, 2010, unpublished), Flemish soccer players (Philippaerts et al., 2006) and Spanish boys (Yague and De La Fuente, 1998) who showed the largest improvement in sprinting ability 18, 12, 0 and 8 months before PHV occurred, respectively. Thereafter, the improvement in sprint times slowed down gradually until the players reached the U15, U16 or U17 squads. Hence, the larger development in sprint ability existed in the younger than older age groups in the current study, possibly because both co-ordination and strength and power increases are contributing to enhanced sprint performance in the young players.

Interestingly, strength and power has been argued to improve the most after gaining PHV due to a large development in muscle mass (Malina et al., 2004a) and a strong relationship has been found between short sprint ability and leg strength in elite senior soccer players (Wisloff et al. 1998). Therefore, the peak development in sprint ability might have been expected to be around or after the time of PHV. However, because of the disruption in motor coordination due to the large increase in standing height which is linked to lengthening of legs and arms at peak height velocity (Roberton and Halverson, 1988) and the rapidly improving co-ordination in the younger boys, the main changes come earlier.

Performance of Slalom agility test from the current study was compared to that of the English Premier League Academy players (Hulse, 2010, unpublished; table 2.9, Chapter 2). Elite youth soccer players from the current study showed a faster completion time of Slalom agility test than the counterparts from the previous study (Hulse, 2010, unpublished) in every age group. The largest difference in performance of Slalom agility test was 0.32 s for the U12 age groups (current vs. previous: 4.36 ± 0.19 s and 4.68 ± 0.31 s) and the smallest difference was 0.10 s for the U18 age groups (4.01 ± 0.15 s and 4.11 ± 0.25 s). As both studies recruited participants from the English Premier League Academies and the tests were conducted on the same pitch surface there could have been differences in player selection criteria between the clubs from the current and previous (Hulse, 2010, unpublished) studies possibly due to a difference in tactical considerations. For example, an academy that is choosing a tactic to use individual dribbling as a main tool to create goal scoring chances may focus largely on speed and agility as quick changes of direction and speed can be key elements to take on defenders and to decide important outcome of the game (Svensson and Drust, 2005). Whereas, an academy with a tactic which employs passing as a main tool in attacking may put less weight on speed and agility in player selection criteria and may focus more on technical elements. A further possible reason for varying performance in sprint and agility tests between studies is a variation in environmental temperature. Environmental temperature was not recorded consistently in the Hulse (2010, unpublished) study but where it was recorded, it was between 10.5 and 12.4 ºC. In the present study, temperature varied from 12.0-23.0 ºC which might account for some of the different in sprint and agility times between studies (Mureika, 2006).

The performance of Slalom agility test continued improving with chronological age until the age of 17. The rate of development was the highest between the U9 and U10 squads and the rate of development slowed slightly but stayed similar between the U10 to U13 squads. From the U13 squad, the rate gradually slowed down and the development eventually stopped at the U17 squad. Moreover, performance from the 505 agility test improved as the players aged until they reached the U17 squad. The highest rate of development in performance for the 505 agility test was observed between the U11-U12 squads and the rate decreased as the players aged. These results suggest that agility develops the most when the elite youth soccer players are younger than older. As agility is a combination of strength, speed, balance and coordination (Draper and Lancaster, 1985), it is reasonable that the performance of Slalom agility test improved the most at an early age due to a lack of coordination and balance in the younger compared to the older players (Whitall, 2003). Also it is understandable to observe termination of the development in sprint times and Slalom agility test performance at the same or similar time (U17) as speed is a key element in agility. For 505 agility test, the test consisted of straight running and only one turn rather than the repetitive turning included in Slalom agility test. Therefore, it is expected that the developmental pattern of 505 agility test (peak development: U11-U12) performance is different to Slalom agility test (U10-U13) and it was closer to that of sprints (U11-U12).

The squat jump performance of elite youth soccer players from the current study was similar to that of players from the English Premier League Academies (Hulse, 2010, unpublished) and Scotland (McMillan et al., 2005b) and was lower than that of players from Tunisia (Chamari et al., 2004) in the U17 age group (current vs. previous: 39 ± 4 cm vs. 51.3 ± 6.7 cm) and France (Taiana et al., 1993) in the U18 age group (38 ± 5 cm vs. 45.3 ± 2.1 cm). Performance of counter movement jump without arms from elite youth soccer players recruited in the current study was similar to that of players from the English Premier League Academies (Hulse, 2010, unpublished) and lower than that of Scottish players (McMillan et al., 2005b) in the U17 age group (current vs. previous: 40 ± 4 cm vs. 53.4 ± 4.2 cm) and French players (Taiana et al., 1993) in the U18 age group (41 ± 5 cm vs. 50.3 ± 4.1 cm). Elite youth soccer players from the current study showed a similar jump height from counter movement jump with arms to the counterparts from Belgium (Vaeyens et al., 2006) and France (Le Gall et al., 2010). However, performance of counter movement jump with arms observed in the current study was lower than that of the English Premier League Academy players (Hulse, 2010, unpublished), French players (Le Gall et al., 2010; Taiana et al., 1993), international players belonged to English clubs (Reilly et al., 2000) and Norwegian players (Helgerud et al., 2001). For example, the performance of counter movement jump with arms from the current study and French players who competed at international standard (Le Gall et al., 2010) in the U15 age group was 42 ± 4 cm and 50.6 ± 6.4 cm (table 2.10, Chapter 2).

Performance of standing vertical jumps improved from the U9 squad until the players reached the U16 (counter movement jump without arms) or U17 (squat jump and counter movement jump with arms) squad. The largest improvement in performance of the squat jump and counter movement jump without arms occurred between the U10 and U12 squads, and the largest improvement in counter movement jump with arms occurred between the U11 and U13 squads. These timings are the same or similar to the timing of PHV (between the U12 and U13 squads) and peak body mass velocity (between the U13 and U14 squads) which is in line with the development in jumping ability for the English Premier League Academy players (Hulse, 2010, unpublished) and Flemish male soccer players (Philippaerts et al., 2006). In sedentary adolescent males, it has been argued that the maximal increase in muscular strength and power occurs after PHV and closer to peak body mass velocity due to gains in muscle mass (Malina et al., 2004a). Furthermore, leg strength and performance of counter movement jump with arms are strongly related in elite senior soccer player (Wisloff et al., 1998). This diversity in the timing of gaining peak velocity in vertical jump height and strength and power is possibly due to a loss of coordination from a large change in physical size such as standing height and body mass around the tie of PHV as previously described in relation to sprint and agility performances (Roberton and Halverson, 1988).

By the age of 17 years in the present study, the performance of the Yo-Yo intermittent recovery test (level 1) (2315 ± 310 m) seemed to have reached a similar level to elite professional soccer players who were competing in European Champions League (2260 ± 80 m; Mohr et al., 2003). Moreover, the U14 elite youth soccer players from the current study covered a longer distance than the U14 elite soccer players from San Marino (Castagna et al., 2009) during the Yo-Yo intermittent recovery test (current vs. previous: 1887 ± 275 m vs. 842 ± 352 m). To the author’s knowledge, no other information regarding performance of the Yo-Yo intermittent recovery test (level 1) for elite youth soccer players is available. These results suggest that endurance performance is fully developed in the English Premier League

Academy players by the age of 17 years and that the results for younger players compare favourably with European counterparts.

Estimated peak oxygen uptake (estimated using the Multi-stage fitness test) in the present study was similar to that previously reported for the English Premier League Academy players (Hulse, 2010, unpublished) and to international players from English clubs (Reilly et al., 2000). For example, the estimated peak oxygen uptake of the U13 elite youth soccer players from the current study and the English Premier League Academy (Hulse, 2010, unpublished) was 51.0 ± 4.2 and 50.2 ± 4.2 $ml \cdot kg^{-1} \cdot min^{-1}$ respectively. Therefore, the players from the current study possess similar endurance ability compared to the elite soccer players from the previous studies.

Estimated peak oxygen uptake in the present study was also similar to the directly determined (treadmill) peak oxygen uptake for players from Croatia (Jankovic et al., 1993), Italy (Impellizzeri et al., 2006) and Tunisia (Chamari et al., 2004). However, estimated peak oxygen uptake observed from the current study was lower than the directly determined peak oxygen uptake (treadmill running) of the players from Australia (Tumilty, 1993), Denmark (Stroyer et al., 2004), Norway (Helgerud et al., 2001), Scotland (McMillan et al., 2005b) and Tunisia (Chamari et al., 2005). For example, estimated peak oxygen uptake of the U13 elite youth soccer players from the current study and the directly measured peak oxygen uptake of Danish players (Stroyer et al., 2004) was 51.0 ± 4.2 and 58.6 ± 5.0 $ml \cdot kg^{-1} \cdot min^{-1}$, respectively and, estimated peak oxygen uptake of the U17 elite youth soccer players from the current study and directly measured peak oxygen uptake from Tunisian players (Chamari et al., 2004) was 56.9 ± 1.9 and 61.1 ± 4.6 $ml \cdot kg^{-1} \cdot min^{-1}$, respectively. The Multi-stage fitness test has been suggested to underestimate peak oxygen uptake (Sproule et al., 1993; St Clair Gibson et al., 1998) and some of the differences between the players from different countries could be accounted for by the differing methods used (table 2.11, Chapter 2).

Performance of the Yo-Yo intermittent recovery test (level 1) and Multi-stage fitness test improved with chronological age until age 17 in the current study which is consistent with the changes observed in the one other unpublished study examining the English Premier League Academy players (Hulse, 2010, unpublished). However, previous studies on 33 Flemish soccer players (Philippaerts et al., 2006) and Spanish boys (Yague and De La Fuente, 1998) showed a sharp decline in development of endurance ability soon after gaining PHV. This difference may be due to the regular intense training participated in by the English Premier League Academy players from the current and previous (Hulse, 2010, unpublished) studies as it has been suggested that approximately 30% of estimated maximal oxygen uptake can be gained from training per se (Baxter-Jones and Maffulli, 2003).

The largest improvement in performance of the Yo-Yo intermittent recovery test (level 1) occurred between the U10 and U11 squads and a high rate of improvement continued until the players reached the U16 squad. For the Multi-stage fitness test, the largest improvement in performance occurred between the U9 and U11 squads and between the U13 and U15 squads. These findings are similar to those for English Premier League Academy players (Hulse, 2010, unpublished) but at variance with the longitudinal studies conducted on Flemish soccer players (Philippaerts et al., 2006) and Spanish boys (Yague and De La Fuente, 1998) which suggested the largest improvement in endurance ability occurs on or just after PHV. As mentioned above, these differences possibly relate to the regular participation in intense training by the English Premier League Academy players. However, the differences may also due to the use of cross-sectional methods in the present study and longitudinal methods in the Belgian and Spanish studies.

Although the U13 squad was the most successful in terms of match performance, winning all their matches with an average score of four goals to one, the physical performance of this age group did not stand out. Furthermore, it is not possible to say at this stage if any of the performance tests were more valuable than others but it is of interest that the Slalom agility and endurance tests were less influenced by maturity (PHV) than other variables and thus may prove to be of a particular value in talent identification and selection.

When the physical characteristics and physical performances of the players from the current study were compared to that of typical school boy soccer players in England (U10-U18 age groups, N = 300), the academy players were taller, heavier, faster (10 and 20 m sprints; Slalom agility test) and were showing higher jump height (squat jump, counter movement jump without and with arms) than the school boys in the same age group (the same or similar chronological age). The largest differences in physical characteristics (standing height: 4-5 cm, body mass: 2-3 kg) and physical performances between players from the present study and the school boys (10 m sprint: 0.1-0.3 s, 20 m sprint: 0.1-0.5s, Slalom agility test: 0.3-1.1 s, squat jump: 5-7 cm, both counter movement jumps: 4-9 cm) were commonly observed in the U12-U16 age groups (Hulse, 2010, unpublished). Moreover, the Multi-stage fitness test performance of the U9-U17 age groups from the current study was at least 400 m longer than that of sedentary boys (N = 188) in the same age groups (Leger et al., 1988). Therefore, coaches and scouts are advised to seek players with superior physical characteristics and physical performances than the sedentary boys and typical school boy players especially in the U12-U16 age groups.

In conclusion, the greatest changes in anthropometric and performance characteristics between squads were mostly observed in players up to the U13 age group which may reflect the earlier maturity of elite soccer players or/and the changes due to the commencement of training in academy soccer. The physical characteristics and physical performances of elite youth soccer players were similar or better in terms of endurance to those of other English and overseas players and, the majority of physical characteristics and physical performances of the academy players were superior to that of the school boy players. Some changes in physical performance (e.g., sprint times) had ceased by 15 years of age whereas other performance variables (e.g., agility) continued to develop up to the U17 age group. The information on the timing and magnitude of changes in physical characteristics and physical performances of the players will be of great value for coaches/staff in terms of knowing when to, and when not to, wait for players to develop certain physical characteristics or physical performances. Overall, the elite soccer players participating in the study had a similar or better anthropometric and performance profile to other European and English players, but a superior profile in comparison with school boy players. This knowledge will be of value later in the thesis and will set in context the novel information concerning match distances and speeds achieved in these players.

Chapter 5
Match performance of each age group squad of elite youth soccer players

5.1 Introduction

In soccer, there has been a large amount of match analysis conducted on both male and female adults from amateur to elite professional players (Carling et al., 2008). A wide variety of methods have been used for motion analysis during matches, including manual video coding, automatic video tracking, electronic transmitter, computer pen and tablet, triangular surveying and GPSs. Each method has different advantages and limitations and can influence the accuracy of the outcomes (Carling et al., 2008). Recent studies which used a computer pen and tablet, manual video coding or automatic video recording have shown that male professional soccer players covered 10-14 km in a 90 min match (Bradley et al., 2009; Burgess et al., 2006; Di Salvo et al. 2007; Di Salvo et al., 2009; Mohr et al., 2003; Rampinini et al., 2007a; Rampinini et al., 2007b) and the players performed several different types of ball and non-ball activities during a match (Reilly, 2003).

The activities categorised according to linear speed have been standing, walking, jogging or low intensity running, running or moderate intensity running, high intensity running and sprinting (Bradley et al., 2009; Burgess et al., 2006; Di Salvo et al. 2007; Di Salvo et al., 2009; Mohr et al., 2003; Rampinini et al., 2007a; Rampinini et al., 2007b). Although various speed ranges have been employed, the most commonly used speed ranges were 0 $km \cdot h^{-1}$ to ~7 $km \cdot h^{-1}$ for standing and walking, ~7 $km \cdot h^{-1}$ to ~14 $km \cdot h^{-1}$ for jogging or low intensity running, ~14 $km \cdot h^{-1}$ to ~19 $km \cdot h^{-1}$ for running or moderate intensity running and ~19 $km \cdot h^{-1}$ to ~25 $km \cdot h^{-1}$ for high intensity running. Any running with a speed faster than high intensity running has been categorised as sprinting (Bradley et al., 2009; Burgess et al., 2006; Di Salvo et al., 2007; Di Salvo et al., 2009; Rampinini et al., 2007a; Rampinini et al., 2007b).

For adult players, the distances covered were 3400-4000 m for standing and walking, 4000-5000 m for jogging or low intensity running, 1700-1850 m for running or moderate intensity running, ~700 m for high intensity running and 200-650 m for sprinting (Bradley et al., 2009; Burgess et al., 2006; Mohr et al., 2003; Rampinini et al., 2007a). The percentage of time spent in each category during a match was 30-65% for standing and walking, 20-40% for jogging or low intensity running, 6.4% for running or moderate intensity running, 2% for high intensity running and 0.6-2.3% for sprinting (Bradley et al., 2009; Burgess et al., 2006; Mohr et al., 2003; Rampinini et al., 2007a). The range of mean single sprint distance was 7-19 m (Bradley et al., 2009; Di Salvo et al., 2007; Mohr et al., 2003) and sprints were performed 3-40 times in a 90 minute match (Bradley et al., 2009; Di Salvo et al., 2007; Mohr et al., 2003).

In youth soccer, there have been a limited number of match analysis studies. Match running performance of the U15 age group from elite Brazilian youth soccer players (N = 25) were analysed. In an 11 a side match (two 30 minute halves) played on regular size pitch, the Brazilians covered 7077.4 m in average (Pereira Da Silva et al., 2007). Castagna et al. (2009) analysed a 60 min (30 min each half) soccer match of 14 years old elite youth soccer players (N = 21) who belonged to a national youth soccer academy (Federazione Sammarinese Giuoco Calcio, San Marino) using GPS technology. Speed categories created were 0-0.4 $km \cdot h^{-1}$ (standing), 0.4-3.0 $km \cdot h^{-1}$ (walking), 3.0-8.0 $km \cdot h^{-1}$ (jogging), 8.0-13.0 $km \cdot h^{-1}$ (medium-intensity running), 13.0-18.0 $km \cdot h^{-1}$ (high-intensity running) and > 18.0 $km \cdot h^{-1}$ (sprinting). The total distance covered during the match was 6173 m and the players covered 508 m by walking, 2981 m by jogging, 1694 m by medium-intensity running, 741 m by high intensity running and 234 m by sprinting. Castagna and colleagues (2003) also analysed a 60 min (30 min each half) soccer match of 11 years old soccer players (N = 11) from Italy (using a triangular surveying method and created four speed categories which were 0-8 $km \cdot h^{-1}$, 8.1-13.0 $km \cdot h^{-1}$ (medium intensity running), 13.1-18.0 $km \cdot h^{-1}$ (high intensity running) and > 18.0 $km \cdot h^{-1}$ (maximal intensity running). The mean distances covered were 4344 m for 0-8 $km \cdot h^{-1}$, 986 m for medium intensity running, 468 m for high intensity running and 114 m for maximum intensity running. Also in 11 year old Italian soccer players (N = 6), Capranica et al. (2001) found that standing and walking accounted for 42% of the match duration from a manual video coding analysis. However, the percentage of time spent on standing and walking was reported to be higher for older age groups. Manual video recording analyses of Danish elite soccer players (three of the most successful clubs in Denmark) with a mean chronological age of 12.6 (N = 9) and 14.0 (N = 7) years showed that the percentage of time spent standing and walking was 60.7% and 56.9%, respectively of total match time. Also, 31.3% and 34.0% of the match-time was spent jogging and 7.9% and 9.0% of the match-time was spent performing high intensity running (including sprinting) by the younger and older age groups, respectively (Stroyer et al., 2004). Thus there is a dearth of information regarding the match analysis of youth players as the studies were only conducted on 11, 12, 14 and 15 years old soccer players and the players were only from recruited from Brazil, Denmark, Italy and San Marino.

Thus in summary there is a limited volume of research published on the match analysis of youth soccer players and the age groups covered in the literature to date are only 11, 12, 14 and 15 years old boys. Also, most studies on young soccer players have employed fewer speed zones compared to the studies on senior soccer players and only two studies have examined elite players. Moreover, the participants were recruited from limited countries (Brazil, Denmark, Italy and San Marino) and there is no information on the match analysis of elite youth players in the UK. Information on UK players would allow comparison with other European nations, will provide more knowledge regarding the development of players in match play from the U9 to U18 age groups and may provide valuable information for coaches that may assist in creating suitable training programmes and may even, in the long-term, assist in talent identification.

Therefore, the aims of the present study was to examine the match demands of elite U9 to U16 players from the English Premier League Academy and to examine any differences in activity patterns during a soccer match between the age groups. It was hypothesised, based on the information available for adult players, that there would be a difference in activity patterns during a soccer match between different age group squads with the older players covering a greater distance at a greater speed.

5.2 Methods

5.2.1 Participants

The participants were 127 English Premier League Academy players from a club in the East Midlands and their chronological age ranged from 8.4 to 16.2 years. The players were grouped by age into U9 to U16 squads. The standing height and body mass for each squad are listed in table 5.1 and the distribution of playing positions for each squad is listed in table 5.2 and 5.3. In the analysis of this chapter, each player participated in average of 4 matches ranging from 2 to 13 matches. The U9-U14 squads had 3 training sessions a week and the U15 and U16 squads trained 4 times a week. All squads had an average of one match per week during the season. Players were provided with a written and verbal explanation of the study including all tests and measurements to be taken. Each player signed an informed consent form and completed a health screening questionnaire prior to participation in the study. The players' parent, guardian or care-giver signed the consent form prior to the start of the study. Participants were withdrawn from a particular test if they did not have a satisfactory health status. The study was approved by Loughborough University Ethical Committee.

5.2.2 Sprint test

A ten metre sprint test with a split time at 5 m was conducted in September 2008. Sprint times were used to calculate the speed zones for match analysis. Sprint time at 5 and 10 m was averaged for each player to give the 7.5 m sprint time.

Table 5.1 Number of players, standing height and body mass of the players from the U9-U16 squads (N = 127, mean ± SD).

		U9	U10	U11	U12	U13	U14	U15	U16
N		22	12	23	14	14	13	13	16
Standing height (cm)	Mean	136.2	143.0	150.0	153.9	163.0	170.1	176.3	179.0
	SD	5.0	5.7	4.7	5.7	8.5	8.3	5.8	5.2
Body mass (kg)	Mean	31.5	36.6	40.3	45.0	51.5	57.7	66.4	70.1
	SD	3.6	4.2	5.4	5.7	8.5	9.1	5.5	6.2

Table 5.2 Distribution of playing position for the U9 and U10 squads.

	Defenders	Midfielders	Strikers	Mixture
U9	7	3	7	5
U10	5	4	2	1

Table 5.3 Distribution of playing position for the U11-U16 squads.

	Central defenders	Wide defenders	Central midfielders	Wide midfielders	Strikers
U11	4	5	4	5	5
U12	3	2	2	3	4
U13	2	3	3	2	4
U14	4	3	3	1	2
U15	2	0	5	2	4
U16	3	4	3	3	3

5.2.3 Match analysis

Soccer matches were analysed during season 08-09 and 09-10 using a GPS (SPI Elite, GPSport, Australia). This system required players to wear small backpack on their back which contained the device; players wore this equipment throughout the match. Validity of GPS has been reported elsewhere (MacLeod et al., 2009; Barvero-Alvarez et al., 2010). The matches were played on flat grass pitches; pitch dimensions, duration of the matches and player to area ratio are illustrated in table 5.4. The matches were 6-a-side for the U9 and U10 squads and, 11-a-side for the U11-U16 squads. The matches were part of the regular series of inter-academy matches between Premier League Academies during a season. Completion of at least a half of the duration of a match in two separate matches (mean ± SD = 3.5 ± 1.9 matches: range = 2-13 matches) was the criterion for inclusion in the study. Mean values from matches were calculated for each player. Match scores and results of the U11-U16 squads were recorded. As two matches were played at the same time in the U9 and U10 squads, match scores could not be recorded.

Table 5.4 Pitch and penalty area dimensions, duration of matches and area per player for the U9-U16 squads.

<table>
<tr><th></th><th>Pitch dimension (m)</th><th>Penalty area (m)</th><th>Duration</th><th>Area per player ($m^2·plyer^{-1}$)</th></tr>
<tr><td>U9</td><td rowspan="2">44.8 x 26.0</td><td rowspan="2">9.0 x 18.8</td><td rowspan="2">15 min x 4 or (20 min x 2 + 15 min x 2)</td><td rowspan="2">97.1</td></tr>
<tr><td>U10</td></tr>
<tr><td>U11</td><td rowspan="2">78.7 x 54.1</td><td rowspan="2">14.7 x 36.6</td><td>(20 min x 2 + 15 min x 2) or 25 min x 3</td><td rowspan="2">193.5</td></tr>
<tr><td>U12</td><td rowspan="2">25 min x 3</td></tr>
<tr><td>U13</td><td>88.0 x 64.2</td><td rowspan="2">16.5 x 40.3</td><td>256.8</td></tr>
<tr><td>U14-U16</td><td>100.8 x 68.2</td><td>40 min x 2</td><td>312.5</td></tr>
</table>

5.2.4 Match activities

Sprint speeds over 7.5 m were averaged for each squad and five speed zones specific to each age group were calculated based on a mean of average sprint speed over 7.5 m from each squad (walking, jogging, low speed running, moderate speed running and high speed running). The five speed categories were calculated by dividing the speed zones of 0.0 $m·s^{-1}$

to two standard deviations below the squad mean of average sprint speed over 7.5 m into 5 equal categories. Running speeds faster than the fastest speed zone were also included in the high speed running category. The speed zones employed for each squad are listed in table 5.5. The distances covered by the five locomotor categories were estimated using Team AMS software version 1.2 (GPSport, Australia) and they were presented in $m \cdot hour^{-1}$. Also, mean playing time, total distance covered during a match in absolute terms and metres per hour, the percentage of time spent in each speed zone during a match were calculated.

5.2.5 Statistical analyses

One way analysis of variance with Tukey post hoc test was used. The level of statistical significance was set at $p < 0.05$. Results are presented as mean ± standard deviation (SD) and PASW 18.0 was used for all the statistical analyses. Goalkeepers were excluded from all statistical analysis.

Table 5.5 The speed zones for match analyses of the U9-U16 squads presented in $m \cdot s^{-1}$.

	U9	U10	U11	U12	U13	U14	U15 and U16
Standing and walking	0.0 - 1.0	0.0 - 1.0	0.0 - 1.1	0.0 - 1.1	0.0 - 1.1	0.0 - 1.2	0.0 - 1.2
Jogging	1.1 - 2.0	1.1 - 2.1	1.2 - 2.1	1.2 - 2.2	1.2 - 2.2	1.1 - 2.3	1.3 - 2.4
Low speed running	2.1 - 3.1	2.2 - 3.1	2.2 - 3.2	2.3 - 3.2	2.3 - 3.3	2.4 - 3.5	2.5 - 3.7
Moderate speed running	3.2 - 4.1	3.2 - 4.2	3.3 - 4.2	3.3 - 4.3	3.4 - 4.4	3.6 - 4.6	3.8 - 4.9
High speed running	> 4.1	> 4.2	> 4.2	> 4.3	> 4.4	> 4.6	> 4.9

5.3. Results

5.3.1 Chronological age, playing time and match score

Mean chronological age of each squad ranged from 9.2 (± 0.2) years for the U9 squad to 15.9 (± 0.3) years for the U16 squad. Mean playing time during a match ranged from 50.9 min for the U10 squad to 70.4 min for the U16 squad. The players in the U11 squad (60.3 ± 9.3 min) gained a significantly longer playing time compared to the players in the U10 squad ($p < 0.01$) during a match and the players in the U16 squad gained a significantly longer playing time compared to the players in the U9 ($p < 0.05$), U10 ($p < 0.01$), U12 ($p < 0.05$) and U14 ($p < 0.01$) squads (table 5.7).

Table 5.6 Mean number of goals and match results of the U11-U16 (U15 and U16 players were combined to form the U16 squad) squads (N = 127, mean ± SD) and mean number of goals of opposition.

		Score		W	L	D
		Current study	Opposition			
U11	Mean	2	1	5	2	0
	SD	2	1			
U12	Mean	4	2	3	0	1
	SD	2	2			
U13	Mean	4	1	4	0	0
	SD	2	1			
U14	Mean	2	2	3	3	0
	SD	2	1			
U16	Mean	1	1	7	8	3
	SD	1	1			

5.3.2 Distance covered

<u>Total distance</u>

Total distance covered during a match ranged from 4056 ± 541 m for the U10 squad to 7697 ± 1546 m for the U16 squad (table 5.7). The U11-U16 squads covered a significantly longer total distance in a match than the U9 and U10 squads ($p < 0.01$ for all) and, the U15 and U16 squads also covered a significantly longer distance than the U11 and U12 squads ($p < 0.05$

vs. U15 squad and $p < 0.01$ vs. U16 squad for both). Moreover, the U16 squad covered a significantly longer distance than the U13 ($p < 0.05$) and U14 ($p < 0.01$) squads.

When total distance covered during a match was standardised to per hour of a match, there was a gradual increase in total distance covered according to chronological age until age 15 (figure 5.1 and table 5.7). The squad mean of total distance covered per hour of a match ranged from 4675 (± 311) $m \cdot h^{-1}$ for the U9 squad to 6727 (± 268) $m \cdot h^{-1}$ for the U15 squad. The U11-U16 squads covered a significantly greater distance than the U9 and U10 squads ($p < 0.01$ for all). Moreover, the U14 squad covered a significantly greater distance than the U11 squad, the U15 squad covered a significantly greater distance compared to the U11-U14 squads and, the U16 squad covered a significantly greater distance than the U11 and U12 squads per hour of a match ($p < 0.01$ for all).

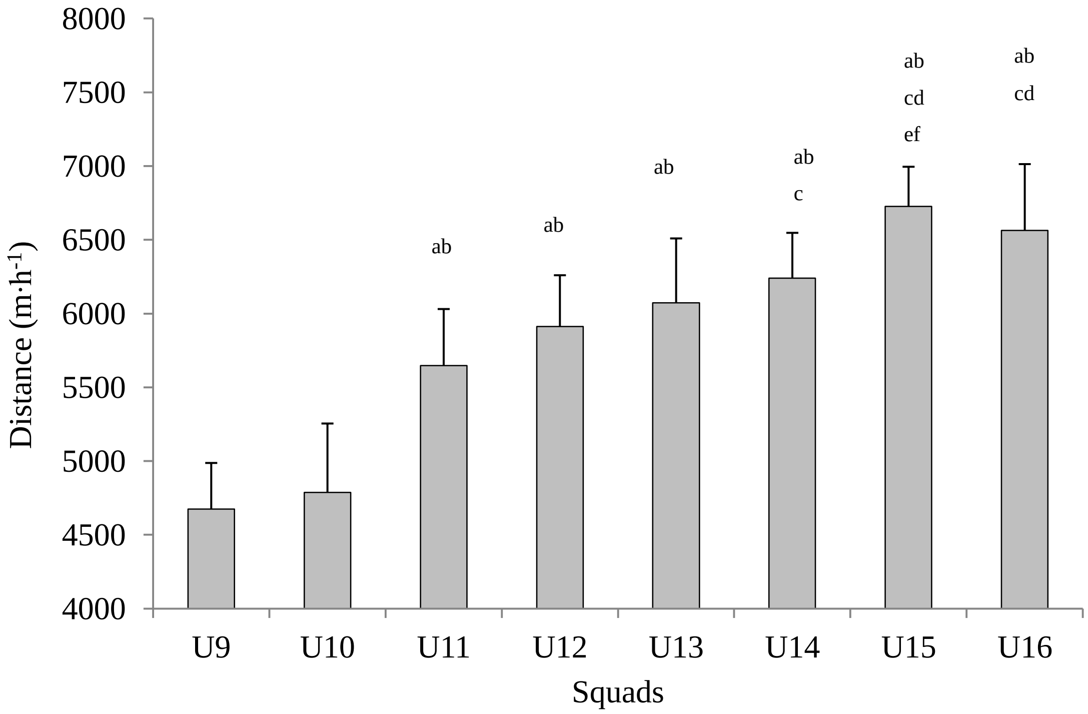


Figure 5.1 Total distance covered per hour of a match (mean ± SD) from each squad. a = $p < 0.01$ vs. U9, b = $p < 0.01$ vs. U10, c = $p < 0.01$ vs. U11, d = $p < 0.01$ vs. U12, e = $p < 0.01$ vs. U13, f = $p < 0.01$ vs. U14.

Table 5.7 Number of participants, chronological age, mean playing time, total distance covered during a match and total distance covered per hour (N = 127, mean ± SD) from each squad.

	N	Chronological age (years)		Mean playing time (min)		Total distance (m)		Total distance ($m \cdot h^{-1}$)	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
U9	22	9.2	0.2	55.9	4.3	4356	478	4675	311
U10	12	9.8	0.4	50.9	5.2	4056	541	4788	466
U11	23	11.3	0.2	60.3^{b}	9.3	5668^{ab}	917	5647^{ab}	383
U12	14	12.1	0.3	55.2	10.7	5415^{ab}	928	5912^{ab}	347
U13	14	13.2	0.3	57.9	9.5	5853^{ab}	1029	6072^{ab}	437
U14	13	14.0	0.3	54.3	8.1	5652^{ab}	969	6240^{abc}	306
U15	13	14.9	0.2	63.7	12.5	7127^{abc*d*}	1310	6727^{abcdef}	268
U16	16	15.9	0.3	70.4^{a*bd*f}	13.2	$7697^{abcde*f}$	1546	6564^{abcd}	448

a = p < 0.01 vs. U9, b = p < 0.01 vs. U10, c = p < 0.01 vs. U11, d = p < 0.01 vs. U12, e = p < 0.01 vs. U13, f = p < 0.01 vs. U14. *P < 0.05.

Walking

The shortest squad mean of distance covered by walking per hour of a match was 946 (± 91) $m \cdot h^{-1}$ for the U13 squad and the longest was 1121 (± 84) $m \cdot h^{-1}$ for the U14 squad. The U14 squad walked a significantly greater distance than the U11 ($p < 0.05$) and U13 ($p < 0.01$) squads. There were no other significant differences in distance walked during a match between the squads (table 5.8).

Jogging

The greatest distance covered by jogging per hour during a match was shown by the U15 squad (2139 ± 147 $m \cdot h^{-1}$) and the lowest was displayed by the U11 squad (1653 ± 179 $m \cdot h^{-1}$) (table 5.8). The U10 and U12-U16 squads jogged a significantly greater distance than the U9 squad per hour of a match ($p < 0.01$ vs. U12, U13, U15 and U16 squads, $p < 0.05$ vs. U10 and U14 squads) and, the U11, U15 and U16 squads jogged significantly greater distance than the U10 squad per hour of a match ($p < 0.01$ vs. U15 squad, $p < 0.05$ vs. U11 and U16 squads). Moreover, the U12-U16 squads covered a significantly greater distance by jogging compared to the U11 squad ($p < 0.01$ for all). Furthermore, the U15 and U16 squads jogged a significantly greater distance than the U12 ($p < 0.05$ for both) and U14 ($p < 0.01$ for both) squads.

Low speed running

The mean distance covered by low speed running ranged from 1098 (± 241) $m \cdot h^{-1}$ (U10 squad) to 1978 (± 218) $m \cdot h^{-1}$ (U15 squad). The U9 and U10 squads covered a significantly lower distance by low speed running compared to all the other squads ($p < 0.01$ for all). Moreover, the U15 and U16 squads covered a significantly longer distance by low speed running than the U11 ($p < 0.01$ vs. U15, $p < 0.05$ vs. U16) and U12 ($p < 0.01$ for both) squads (table 5.8).

Moderate speed running

Squad mean of distance covered by moderate speed running per hour of a match ranged from 496 ± 108 $m \cdot h^{-1}$ (U9 squad) to 1042 ± 141 $m \cdot h^{-1}$ (U15 squad). The U9 and U10 squads covered a significantly less distance by moderate speed running compared to all the other squads ($p < 0.01$ for all). However, no significant differences were found between the U11-

U16 squads as well as between the two youngest squads in the distance covered by moderate speed running per hour during a match (table 5.8).

<u>High speed running</u>

Mean distance covered during a match by high speed running from each squad ranged from 178 (± 56) m·h^{-1} (U9 squad) to 553 (± 153) m·h^{-1} (U15 squad). The U9 and U10 squads covered a significantly lower distance by high speed running compared to all the other squads ($p < 0.01$ for all). However, no significant differences were found between the U11-U16 squads. Moreover, there were no significant differences in the distance covered by high speed running per hour of a match between the two youngest squads (table 5.8).

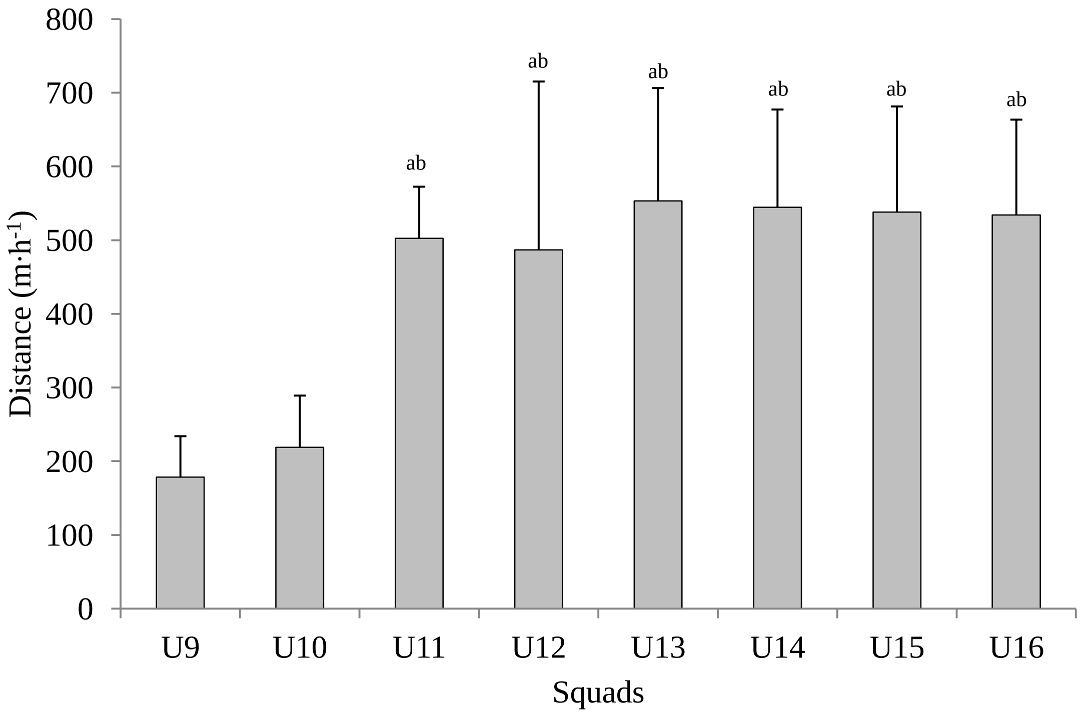


Figure 5.2 Distance covered by high speed running per hour of a match (mean ± SD) from each squad. a = $p < 0.01$ vs. U9, b = $p < 0.01$ vs. U10.

Table 5.8 Number of participants, chronological age, distance covered by different speed zones in a match (N = 127, mean ± SD) from each squad.

	N	Chronological age (years)		Distance ($m \cdot h^{-1}$)					
				Walking		Jogging		Low speed running	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
U9	22	9.2	0.2	1038	71	1673	143	1273	217
U10	12	9.8	0.4	1018	94	1877^{a*}	167	1098	241
U11	23	11.3	0.2	1013	90	1653^{b*}	179	1571^{ab}	232
U12	14	12.1	0.3	1054	90	1911^{ac}	172	1526^{ab}	164
U13	14	13.2	0.3	946	91	1968^{ac}	178	1666^{ab}	271
U14	13	14.0	0.3	1121^{c*e}	84	1869^{a*c}	139	1812^{ab}	285
U15	13	14.9	0.2	1029	72	2139^{abcd*f}	147	1978^{abcd}	218
U16	16	15.9	0.3	1045	133	$2104^{ab*cd*f}$	141	1887^{abc*d}	267

a = $p < 0.01$ vs. U9, b = $p < 0.01$ vs. U10, c = $p < 0.01$ vs. U11, d = $p < 0.01$ vs. U12, e = $p < 0.01$ vs. U13, f = $p < 0.01$ vs. U14. *$P < 0.05$.

Table 5.8 (continued) Number of participants, chronological age, distance covered by different speed zones in a match (N = 127, mean ± SD) from each squad.

	Distance ($m \cdot h^{-1}$)			
	Moderate speed running		High speed running	
	Mean	SD	Mean	SD
U9	496	108	178	56
U10	576	170	219	70
U11	884[ab]	155	502[ab]	70
U12	926[ab]	178	487[ab]	229
U13	939[ab]	226	553[ab]	153
U14	892[ab]	158	545[ab]	133
U15	1042[ab]	141	538[ab]	144
U16	993[ab]	209	534[ab]	130

a = $p < 0.01$ vs. U9, b = $p < 0.01$ vs. U10.

5.3.3 Percentage time

Standing and walking

The highest and lowest percentage of time spent on standing and walking during a match was demonstrated by the U9 (46.4 ± 4.3%) and U15 (37.8 ± 2.9%) squads, respectively (table 5.9). The U13, U15 and U16 squads spent a significantly lower percentage of time standing and walking than the U9 squad ($p < 0.01$ for all) and, the U15 squad also spent a significantly lower percentage of time standing and walking than the U10, U11 and U14 squads ($p < 0.01$ vs. U11 and U14 squads, $p < 0.05$ vs. U10 squad).

Jogging

The squad mean of percentage of time spent on jogging during a match ranged from 29.5 ± 2.9% for the U11 squad to 36.5 ± 2.8% for the U10 squad (table 5.9) with no clear pattern of change across the age groups.

Low speed running

The percentage of time spent on low speed running during a match ranged from 12.6 ± 2.7% (U10 squad) to 18.3 ± 2.0% (U15 squad). The U11-U16 squads spent a significantly higher percentage of time performing low speed running during a match compared to the U10 squad ($p < 0.01$ vs. U11 and U14-U16 squads, $p < 0.05$ vs. U12 and U13 squads). The U15 squad also spent a significantly higher percentage of time performing low speed running during a match compared to the U9 ($p < 0.01$) and U12 ($p < 0.05$) squads (table 5.9). There were no significant differences between the U11-U16 squads.

Moderate speed running

For moderate speed running, the lowest percentage of time was spent by the U9 squad (4.1 ± 0.9%) and the highest percentage of time was spent by the U12 (7.0 ± 1.4%) and U15 (7.0 ± 0.9%) squads during a match. The U9 squad spent a significantly lower percentage of time on moderate speed running during a match compared to the U11-U16 squads ($p < 0.01$ for all) and, the U10 squad spent a significantly lower percentage of time on moderate speed running during a match compared to the U11-U13, U15 and U16 squads ($p < 0.01$ vs. U11, U12 and U15 squads, $p < 0.05$ vs. U13 and U16 squads). There were no significant differences in percentage of time spent on moderate speed running between the U9 and U10 squads and, between the U11-U16 squads during a match (table 5.9).

High speed running

The percentage of time spent on high speed running during a match ranged from 1.1 ± 0.3% (U9 squad) to 3.0 ± 0.8% (U13 squad). The U9 and U10 squads spent a significantly lower percentage of time on high speed running during a match compared to the U11-U16 squads ($p < 0.01$ for all). Moreover, there were no significant differences in the percentage of time spent on high speed running during a match between the U9 and U10 squads and, between the U11-U16 squads (table 5.9).

Table 5.9 Number of participants, chronological age, percentage time spent on different speed zones in a match (N = 127, mean ± SD) from each squad.

	N	Chronological age (years)		Percentage time (%)					
				Standing and walking		Jogging		Low speed running	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
U9	22	9.2	0.2	46.4	4.3	33.2	2.6	15.0	2.4
U10	12	9.8	0.4	44.8	5.8	36.5^{a*}	2.8	12.6	2.7
U11	23	11.3	0.2	44.0	4.7	29.5^{ab}	2.9	16.7^{b}	2.4
U12	14	12.1	0.3	41.8	4.3	32.8^{b*c*}	2.7	15.7^{b*}	1.8
U13	14	13.2	0.3	39.3^{a}	4.4	33.9^{c}	3.3	16.9^{b*}	2.7
U14	13	14.0	0.3	43.7	3.1	29.9^{abe*}	2.2	17.3^{b}	2.7
U15	13	14.9	0.2	37.8^{ab*cf}	2.9	34.2^{cf}	2.2	18.3^{abd*}	2.0
U16	16	15.9	0.3	39.4^{a}	4.7	33.8^{cf}	2.3	17.5^{b}	2.4

a = p < 0.01 vs. U9, b = p < 0.01 vs. U10, c = p < 0.01 vs. U11, d = p < 0.01 vs. U12, e = p < 0.01 vs. U13, f = p < 0.01 vs. U14. *P < 0.05.

Table 5.9 (continued) Number of participants, chronological age, percentage time spent on different speed zones in a match (N = 127, mean ± SD) from each squad.

	Percentage time (%)			
	Moderate speed running		High speed running	
	Mean	SD	Mean	SD
U9	4.1	0.9	1.1	0.3
U10	4.8	1.4	1.3	0.4
U11	6.8[ab]	1.2	2.9[ab]	0.8
U12	7.0[ab]	1.4	2.7[ab]	1.2
U13	6.9[ab*]	1.7	3.0[ab]	0.8
U14	6.2[a]	1.1	2.8[ab]	0.7
U15	7.0[ab]	0.9	2.7[ab]	0.7
U16	6.6[ab*]	1.4	2.6[ab]	0.6

a = p < 0.01 vs. U9, b = p < 0.01 vs. U10. *P < 0.05.

5.4 Discussion

The main findings of the present study were that the total distance covered during a match ranged from 4056 m (U10) to 7697 m (U16). The total distance covered *per hour* of a match ranged from 4675 $m \cdot h^{-1}$ for the U9 squad to 6727 $m \cdot h^{-1}$ for the U15 squad. The percentage of time spent in moderate speed running ranged from 4.1% (U9) to 7.0% (U15) and percentage of time spent in high speed running ranged from 1.1% (U9) to 3.0% (U13).

The total distance covered and the distances covered per hour in the present study were similar to those distances reported earlier for the limited age groups that have been previously examined. The U15 age group from the current study covered a total distance of 6727 $m \cdot h^{-1}$ during a match and this was similar to the distance covered (7077 $m \cdot h^{-1}$) by U15 elite Brazilian soccer players (Pereira Da Silva et al., 2007) who were analysed using video recording with a use of stride length in different activities to calculate distances covered (Withers et al., 1982). Moreover, the U14 squad from the current study covered 6240 $m \cdot h^{-1}$ and this is similar to a total distance covered by 14 years old elite soccer players from San Marino (6173 $m \cdot h^{-1}$) during a 60 minute match (Castagna et al., 2009). The San Marino study used the same method as the current study to analyse the match (GPS). Furthermore, the U11 squad from the current study covered 5647 $m \cdot h^{-1}$ during a match while total distance covered by 11 years old Italians during a 60 minute match was 6175 m (Castanga et al., 2003). These slight differences in distance run for the 11 year olds may be due to differences in methods (Carling et al., 2008) as Castagna et al. (2003) employed a triangular surveying method opposed to GPS in the current study. Thus where comparisons can be made with other young age group players the distances run in the present study are similar to those previously reported, but this study greatly extends previous findings by reporting for the first time on the match running performance of the U9, U10, U13 and U16 players.

There has been a great deal of previous work on the distance covered by senior professional soccer players and a finding of the present study is that the older age group players in this study were covering a similar distance per hour to professional players. For example, senior professionals have been reported to cover between 6667 $m \cdot h^{-1}$ and 9396 $m \cdot h^{-1}$ (Bradley et al., 2009; Burgess et al., 2006; Di Salvo et al. 2007; Di Salvo et al., 2009; Mohr et al., 2003; Rampinini et al., 2007a; Rampinini et al., 2007b) whereas the U15 and U16 players in the present study covered 6727 $m \cdot h^{-1}$ and 6564 $m \cdot h^{-1}$, respectively. Hence, the elite youth soccer players from the current study were reaching the standard of professional soccer players in terms of total distance covered during a match when they were 15 years old. However, the mean playing time of the U15 and U16 squads was 63.7 and 70.4 minutes respectively and the outcomes could have been different if the youth players had completed a 90 minute match due to a decline in work rate towards the end of a match (Krustrup et al., 2003; Mohr et al., 2003).

A large increase in total distance covered per hour of a match was observed between the U10 and U11 squads. The differences in match conditions between the U10 and U11 squads were differences in the number of players included in the matches (U10: 6-a-side, U11: 11-a-side) and varying pitch dimensions (U10: 44.8 m x 26.0 m, U11: 78.7 m x 54.1 m). It has been shown that the number of players does not influence the total distance covered during a match when area per player is the same (Hill-Haas et al., 2009). Hence, the large increase in total distance covered between the U10 and U11 squads is likely to be due to a difference in the area per player as the area per player for the U11 players (193.5 m^2) is twice of that of the U10 players (97.1 m^2). Moreover, a large increase in total distance covered per hour of a match was also observed between the U14 and U15 squads. This is possibly due to issues relating to player selection. Only approximately half of the U14 squad are retained in the academy and included in a combined U15/U16 age group. Thus, the U15 players will have been of a higher standard in terms of performance than the U14 group. Thus coaches need to be aware that the playing demands change greatly with variations in pitch size (e.g., from U10 to U11) and that players may become more fatigued or require greater rest times or fewer matches when the pitch size is changed. Conversely, coaches can be confident that the U15 players are ready to cope with the match distances run in senior squads as the U15 players are already covering a similar distance in their junior matches.

The distance walked per hour during a match was similar for all the squads and it ranged from 946 $m \cdot h^{-1}$ for the U13 squad to 1121 $m \cdot h^{-1}$ for the U14 squad. The only exception was that the U14 squad walked significantly greater than the U11 and U13 squads. The U14 squad from the current study walked a greater distance than 14 years old elite soccer players from San Marino (508 $m \cdot h^{-1}$). However, the speed zone of walking for the current study (0.0-1.2 $m \cdot s^{-1}$) was wider than the speed zone employed in the previous study (0.1-0.8 $m \cdot s^{-1}$)

(Castagna et al., 2009) which possibly explains why the players from the current study walked a greater distance that the U14 elite soccer players from San Marino.

There was a gradual increase in distance jogged per hour of a match with chronological age until 15 and it ranged from 1653 (U9 squad) to 2140 (U15 squad) $m \cdot h^{-1}$. The U14 squad for the current study covered 1868 $m \cdot h^{-1}$ by jogging and this is less than the distance observed for 14 years old elite soccer players from San Marino (2981 $m \cdot h^{-1}$) (Castagna et al., 2009). Moreover, when walking and jogging distances per hour of a match were combined, the U11 squad from the current study covered 2665 $m \cdot h^{-1}$ and this is also less than the distance covered by 11 year old Italians (4344 $m \cdot h^{-1}$) (Castagna et al., 2003). The changes in distance covered by jogging per hour of a match were not uniform and there were some declines as well as improvements as the players aged. Therefore, distance jogged per hour of a match may not be an important aspect when monitoring players' match performance development.

The distance covered by low speed running per hour of a match, ranged from 1098 $m \cdot h^{-1}$ for the U10 squad to 1978 $m \cdot h^{-1}$ for the U15 squad. The U14 squad from the current study (1812 $m \cdot h^{-1}$) covered similar distance to the 14 year old elite soccer players from San Marino (1694 $m \cdot h^{-1}$) (Castagna et al., 2009). Moreover, the U11 squad from the current study (1571 $m \cdot h^{-1}$) covered a greater distance than 11 years old Italians (986 $m \cdot h^{-1}$, Castagna et al., 2003) by low speed running despite the narrower speed zone (2.2-3.2 $m \cdot s^{-1}$ for the current study vs. 2.3-3.6 $m \cdot s^{-1}$ for the previous study). Thus, players in the present study covered a similar or greater distance compared to other European players at low speeds. Furthermore, there was an increase in the distance covered per hour of a match by low speed running with chronological age in elite youth soccer players in the present study, which may be due to the increase in area per player (Hill-Haas et al., 2009). On the other hand, improved endurance ability of the older players (see Chapter 4) may have influenced the increase in distance covered by low speed running as an improvement in endurance ability has been shown to increase the distance covered during a match in elite Norwegian youth players (Helgerud et al., 2001).

The distance covered by moderate speed running ranged from 496 $m \cdot h^{-1}$ (U9) to 1042 $m \cdot h^{-1}$ (U15). The U14 squad from the current study covered 892 $m \cdot h^{-1}$ by moderate speed running during a match and this is similar to the results of 14 years old elite soccer players from San Marino (741 $m \cdot h^{-1}$) (Castagna et al., 2009). Moreover, the distance covered by high speed running per hour of a match ranged from 178 $m \cdot h^{-1}$ for the U9 squad to 553 $m \cdot h^{-1}$ for the U13 squad. There were no differences in distance covered by moderate speed running and high speed running per hour of a match between the U11-U16 squads and, between the U9 and U10 squads. Furthermore, the U11-U16 squads covered a significantly longer distance per hour of a match by moderate speed running and high speed running compared to the U9 and U10 squads. There was a difference in a number of players included in the matches between the U9 and U10 squads and the U11-U16 squads (U9 and U10: 6-a-side, U11-U16: 11-a-side). However, when the area per player is similar, player number has been reported not to influence the distance covered (Hill-Haas et al., 2009). Whereas, a match with a greater area per player has been shown to provide a higher relative heart rate, blood lactate concentration and perceived exertion regardless of player number (Rampinini et al., 2007c). Therefore, a potential rationale for the difference in distance covered by moderate speed running and high speed running between the U9 and U10 squads and the U11-U16 squads is the difference in area per player as the area per player of the U11-U16 squads (193.5-312.5 m^2) is twice or more than that of the U9 and U10 squads (97.1 m^2). However, the previously published studies only included the small sided games of up to 6 vs. 6 (Hill-Haas et al., 2009; Rampinini et al., 2007c) and the findings may have been different if 11 vs. 11 matches were included.

The U12 squad had a large standard deviation in distance covered by high speed running per hour of a match compared to the other squads (U12: 229 $m \cdot h^{-1}$, other squads: 56-153 $m \cdot h^{-1}$). This is possibly due to a variation in start of the adolescent growth spurt which may have created a large range in physical characteristics of the players between the early and late maturers (Malina et al., 2004b; Tanner et al., 1966).

In addition to distances run per match and distances run per hour, this study also examined the percentage of time spent at different speeds. With the exception of jogging where a similar percentage of time (range 30-37%) was spent by all squads, the U9 and U10 squads spent a greater percentage of time walking but a lower percentage of time at low, moderate and high speeds than the U11-U16 age groups. When the area per player is similar, the relative time spent in all speed zones from walking to sprinting has been shown to be similar during a 5-a-side and 11-a-side match (Gabbett and Mulvey, 2008). Therefore, a possible reason for the difference in the relative time spent in different speed zones between the U9 and U10 squads and the U11-U16 squads is the large difference in area per player between the former and latter squads (U9 and U10: 97.1 m^2, U11-U16: 193.5-312.5 m^2). Therefore, the pitch dimension of the U9 and U10 matches would need to be expanded to provide a similar area per player to the U11-U16 matches if coaches aspire to the U9 and U10 squads to spending a similar relative time in each speed zone to the older squads. Comparison with other studies is difficult because of the different match analysis methods used, but on balance, it seems that the players in the present study spent a similar proportion of time walking and jogging but a lower proportion of time (3% vs. 8-9%) in high speed running than other European boys (Capranica et al., 2001; Stroyer et al., 2004). The higher percentage of time at high speed running in the study of Danish players could, however, have been due to the use of manual video coding in that study (Stroyer et al., 2004).

When five speed zones were created based on average sprint speed over 7.5 m, the U11-U16 squads from the current study and senior professional soccer players from the English Premier League demonstrated a similar percentage of time spent on moderate speed running (Current vs. Senior = 6.2-7.0% vs. 6.4%), high speed running including sprinting in the seniors (2.6-3.0% vs. 2.6%) during a match. This indicates that the high intensity activity pattern during a match is similar between the English Premier Academy players and the professional players from the English Premier League.

In conclusion, the total distance covered during a match ranged from approximately 4-8 km for elite youth players and most of this distance was covered at walking, jogging and low speed running pace. The older players (U11-U16) walked less and undertook more relative high speed running than the younger players (U9 and U10). This was probably due to a large difference in area per player during the matches of the younger and older players. Therefore, the pitch dimensions for matches for younger players would need to be enlarged to provide a similar player to area ratio to the older players if the coaches and staff aspired to have the younger players covering a similar relative distance by high intensity running during a match.

Chapter 6

The relationship between field tests and match performance in elite youth soccer players

6.1 Introduction

In elite soccer field-based performance tests, often referred to as 'fitness tests', are widely used to monitor players and there are extensive data available on the physical characteristics of senior (Clark et al., 2008; Cometti et al., 2001; Dunbar and Power, 1997; Edwards et al., 2003; Impellizzeri et al., 2006; Krustrup et al., 2003; Puga et al., 1993; Rampinini et al., 2007a; Rienzi et al., 2000; Wisloff et al., 2004; Zerguini et al., 2007) and youth players (Chamari et al., 2004; Hulse, 2010, unpublished; McMillan et al., 2005b; Reilly et al., 2000; Stroyer et al., 2004; Chapter 4). Such field tests are of value in monitoring the physical development of players with age and maturity and the adaptations to training. However, such tests would have additional value for players and coaches if it were known which performance tests best related to match performance. For example, if there were tests that adequately predicted match distances run and the distances covered at high speeds, there would be less need for video and GPS analysis, which is expensive, time consuming and often not available at all for youth players.

However, only three studies have examined the validity of field tests as an indicator of match performance and the field tests examined were only the Yo-Yo intermittent recovery test (level 1) (Castagna et al., 2009; Krustrup et al., 2003), repeated sprint ability (Rampinini et al., 2007a), the University Montreal Track Test (Rampinini et al., 2007a) and counter movement jump with arms (Rampinini et al., 2007a). There was a strong positive relationship between performance during the Yo-Yo intermittent recovery test (level 1) and, total distance covered and high intensity running distance during a match in the 14 year old elite Sammarinese soccer players (Castagna et al., 2009) and elite professional soccer players (Krustrup et al., 2003). Moreover, when elite professional soccer players were split into two groups based on their field test performances, the group with a better repeated sprint ability and faster peak speed in the University Montreal Track Test showed a significantly longer high intensity running distance during a match than the other group (Rampinini et al., 2007a). However, no such differences in high intensity running distance during a match was observed when the players were separated into two groups based on a performance during a counter movement jump with arms (Rampinini et al., 2007a).

Thus at present there is very limited information available, based almost entirely on senior players and on a limited number of performance tests, on the relationships between field test performance and match performance Hence the aim of the current study was to examine the relationship between a wide variety of field tests and match running performance in elite youth soccer players from the U9 to U16 age groups.

6.2 Methods

6.2.1 Participants

The participants were 66 Premier League Academy players (table 6.1) from a club in East Midlands and their chronological age ranged from 8.4 to 16.1 years. The U9-U14 squads had 3 training sessions a week, the U15 and U16 squads had 4 training sessions a week. All squads had average of one match a week during a season. The measurements were taken in the season 2008-09 and 2009-10. Players were provided with a written and verbal explanation of the study including all tests and measurements to be taken. Each player signed an informed consent form and completed a health screen questionnaire prior to participation in the study. Participants were withdrawn from a particular test if they did not have a satisfactory health status. The study was approved by Loughborough University Ethical Committee.

6.2.2 Field tests

The field tests used were as described in Chapter 3. In brief, the field tests were 30 m sprint with split times at 5, 10, 15 and 20 m, Slalom agility test, 505 agility test (Draper and Lancaster, 1985), squat jump, counter movement jump without arms, counter movement jump with arms, the Yo-Yo intermittent recovery test (level 1) (Bangsbo, 2005), and the Multi-stage fitness test (Ramsbottom et al., 1988).

6.2.3 Match analysis

The match analysis procedures used were as described in Chapter 3. The mean of the performance data for two or more matches was accepted to represent the match performance for that player. Two matches for each squad were analysed within two months of the performance testing date. As the squads played on Sundays and only one squad could be analysed per match day this testing arrangement placed the performance tests and matches as close as was possible. Only the match running performance variables related to high intensity activities (total distance covered per hour of a match, distance covered by and percentage of time spent on moderate and high speed running) were included in the analysis as it has been reported that high intensity activities are more important in distinguishing the standard of soccer players (Bangsbo et al., 1991; Mohr et al., 2003).

6.2.4 Statistics

All the players except the U9 and U10 squads were analysed together. The U9 and U10 were omitted from the whole group analysis because their matches involved 6 players in each team whereas for all other squads the matches involved 11 players in each team (see Chapter 5). As chronological age influences performance (Chapter 4), the participants were also separated into three groups (U9 and U10 squads, U11, U12 and U13 squads and, U14, U15 and U16 squads) and statistical analyses were also conducted separately on each group. Total distance covered and distances covered in the different speed zones were standardised by expressing the results per hour of a match play as players rarely completed a full match and generally different match durations were applied to different age groups. Pearson's product-moment correlation was used to examine the relationship between field test results and match performance. Multiple regression was employed to verify the influence of the chronological age and field test performance on high intensity match running performance for the whole group where the participant numbers were adequate for this analysis. The level of statistical significance was set at $p < 0.05$ and goalkeepers were excluded from all statistical analysis and data presented. Results are presented as mean ± standard deviation (SD) and PASW 18.0 was used for all the statistical analyses.

Table 6.1 Chronological age, number of participants and anthropometry from each group.

	N	Chronological age (years)		Standing height (cm)		Body mass (kg)	
		Mean	SD	Mean	SD	Mean	SD
Whole group (U11-U16)	40	13.7	1.8	165.6	13.1	54.2	13.2
U9 & U10	26	9.4	0.5	140.0	5.8	34.1	4.9
U11-U13	20	12.0	0.6	153.9	5.2	42.9	5.4
U14-U16	20	15.6	0.5	177.4	6.0	65.5	7.9

6.3 Results

6.3.1 Whole group (U11-U16)

Field tests

The mean sprint time for the 5, 10, 15, 20 and 30 m were 1.05 ± 0.07 s, 1.83 ± 0.12 s, 2.54 ± 0.17 s, 3.22 ± 0.22 s and 4.57 ± 0.35 s, respectively. For the Slalom and 505 agility tests, the mean completion times were 4.31 ± 0.20 s and 2.43 ± 0.13 s, respectively. The mean jump height from the standing vertical jumps were 33 ± 5 cm for the squat jump, 35 ± 5 cm for the counter movement jump without arms and 40 ± 6 cm for the counter movement jump with arms. Moreover, the mean performance of the Yo-Yo intermittent recovery test (level 1) and Multi-stage fitness test were 1729 ± 538 m and 1917 ± 304 m, respectively.

Match performance

The mean total distance covered per hour of a match was 6238 ± 521 $m \cdot h^{-1}$. The mean distance covered per hour of a match was 958 ± 155 $m \cdot h^{-1}$ for moderate speed running and 505 ± 143 $m \cdot h^{-1}$ for high speed running. The mean percentage of time spent during a match was 6.8 ± 1.1% for moderate speed running and 2.7 ± 0.8% for high speed running. The mean playing time was 64.0 ± 11.4 min in a match.

Relationship between field tests and match performance

Chronological age

Chronological age showed a significant negative relationship with sprint times (r = -0.78 to -0.57, $p < 0.01$) and agility test performances (r = -0.81 to -0.62, $p < 0.01$) and, showed a significant positive relationship with jump height of standing vertical jumps (r = 0.45 to 0.59, $p < 0.01$) and endurance test performances (r = 0.69 to 0.73, $p < 0.01$). Moreover, chronological age showed a significant positive relationship with total distance covered per hour of a match (r = 0.65, $p < 0.01$) and the percentage of time spent in moderate speed running (r = -0.32, $p < 0.05$) and high speed running (r = -0.34, $p < 0.01$) during a match. No other significant relationships were shown between chronological age and field test performances or between chronological age and match running performances.

Sprints

Sprint time over 5, 10, 15, 20 and 30 m showed a significant negative relationship with the total distance covered per hour of a match ($r = -0.59$ to -0.43, $p < 0.01$ for all: figure 6.1). Thus, the faster the sprint performance the greater the distance covered during the match. No other relationships were shown between sprint times and match running performances.

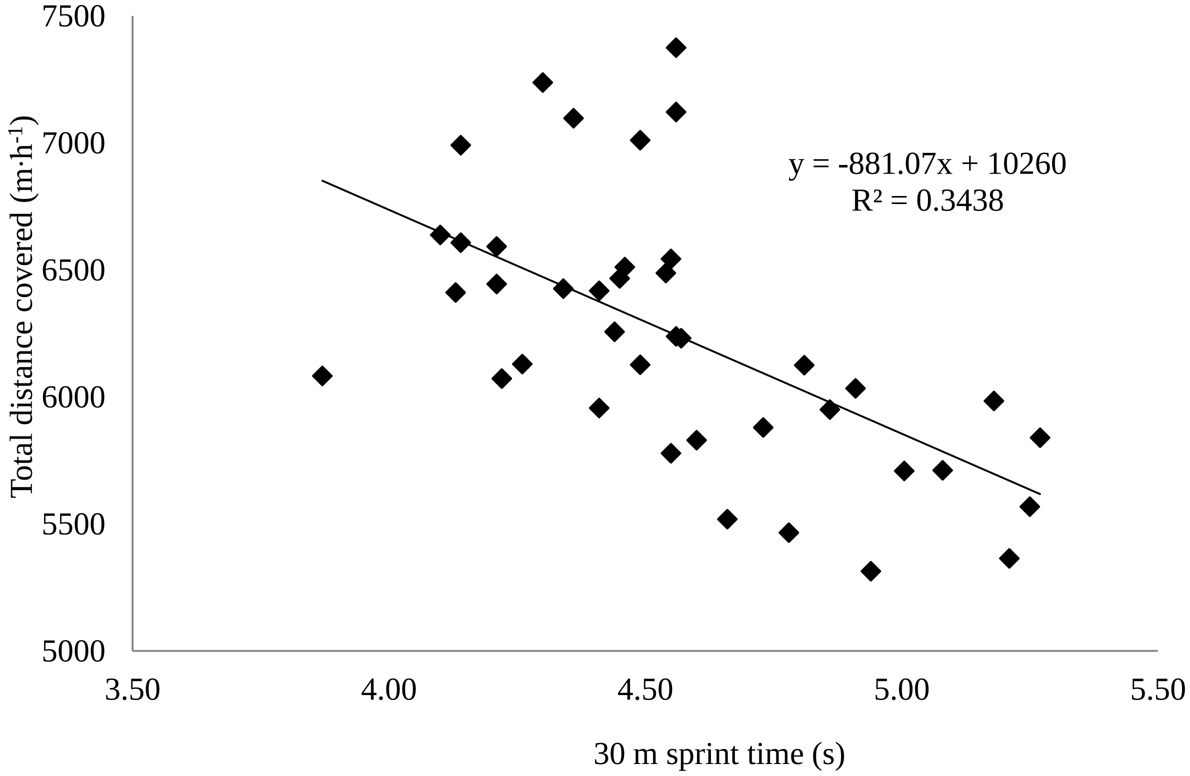


Figure 6.1 The relationship between 30 m sprint time and total distance covered per hour of a match.

Agility tests

For Slalom agility test performance, a significant negative relationship was shown with total distance covered per hour of a match ($r = -0.46$, $p < 0.01$). So the faster the agility test performance, the greater the distance covered during a match. Moreover, the faster the performance of 505 agility test, greater the total distance covered per hour of a match ($r = -0.57$, $p < 0.01$: figure 6.2). No other significant relationships were shown between both the Slalom and 505 agility tests and any of the match running performances.

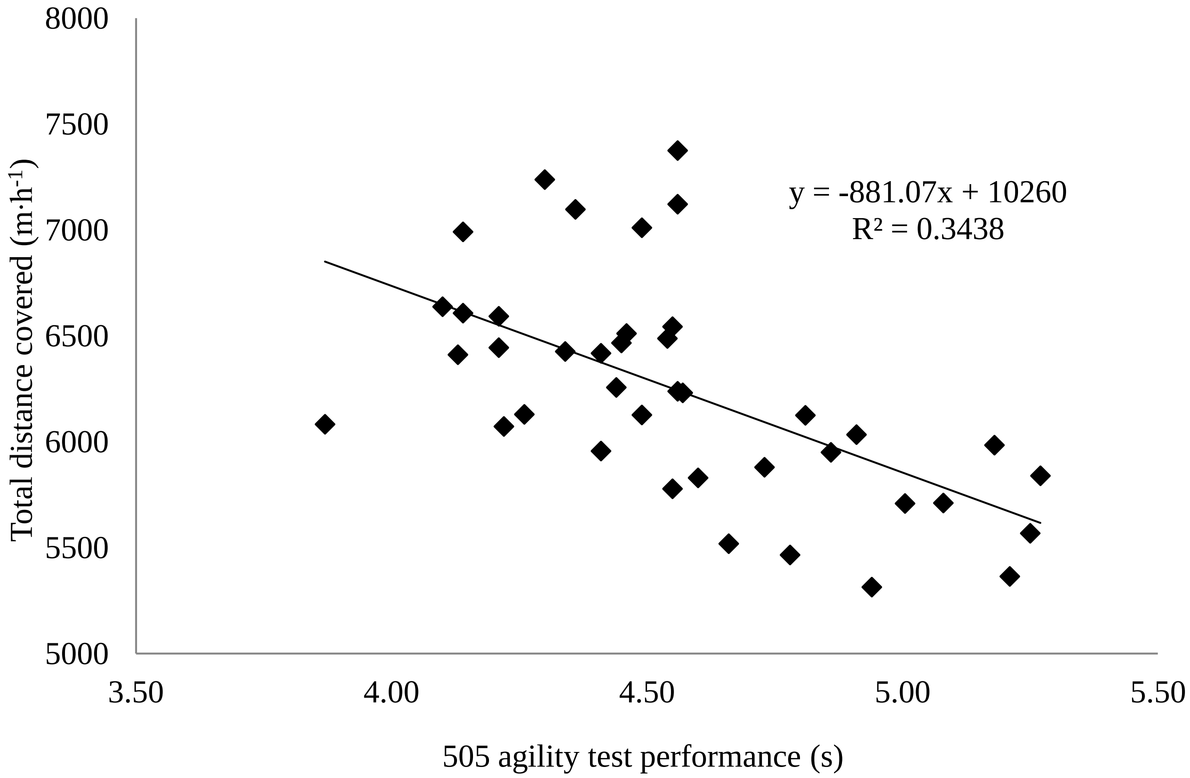


Figure 6.2 The relationship between 505 agility test performance and total distance covered per hour of a match.

Standing vertical jumps

Total distance covered per hour of a match showed a significant relationship with counter movement jump without arms ($r = 0.36$, $p < 0.05$) and counter movement jump with arms ($r = 0.42$, $p < 0.01$: figure 6.3). There were no other significant relationships found between standing vertical jump performances and match running performances.

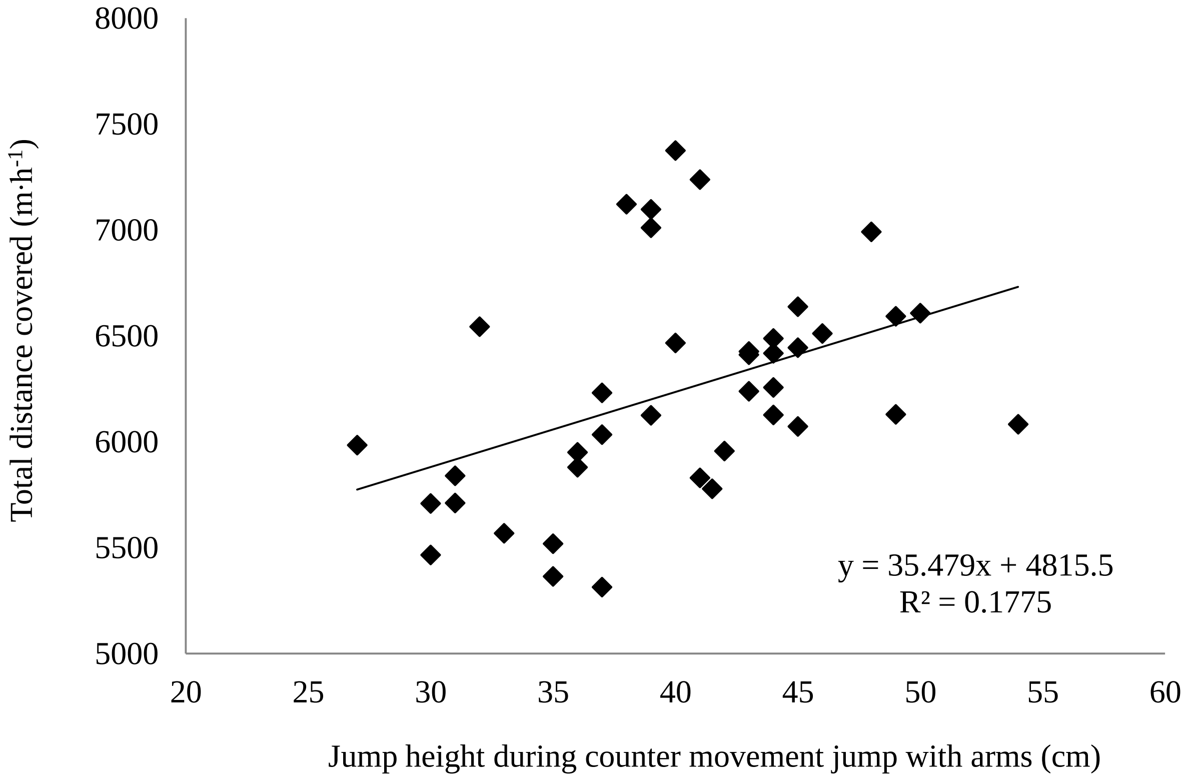


Figure 6.3 The relationship between the jump height during counter movement jump with arms and total distance covered per hour of a match.

Endurance tests

For the Yo-Yo intermittent recovery test (level 1) performance, a significant positive relationship was shown with total distance covered per hour of a match ($r = 0.56$, $p < 0.01$). Moreover, performance during the Multi-stage fitness test illustrated a significant positive relationship with total distance covered per hour of a match ($r = 0.65$, $p < 0.01$: figure 6.4). No other significant relationships were shown between endurance field test performance and match running performances.

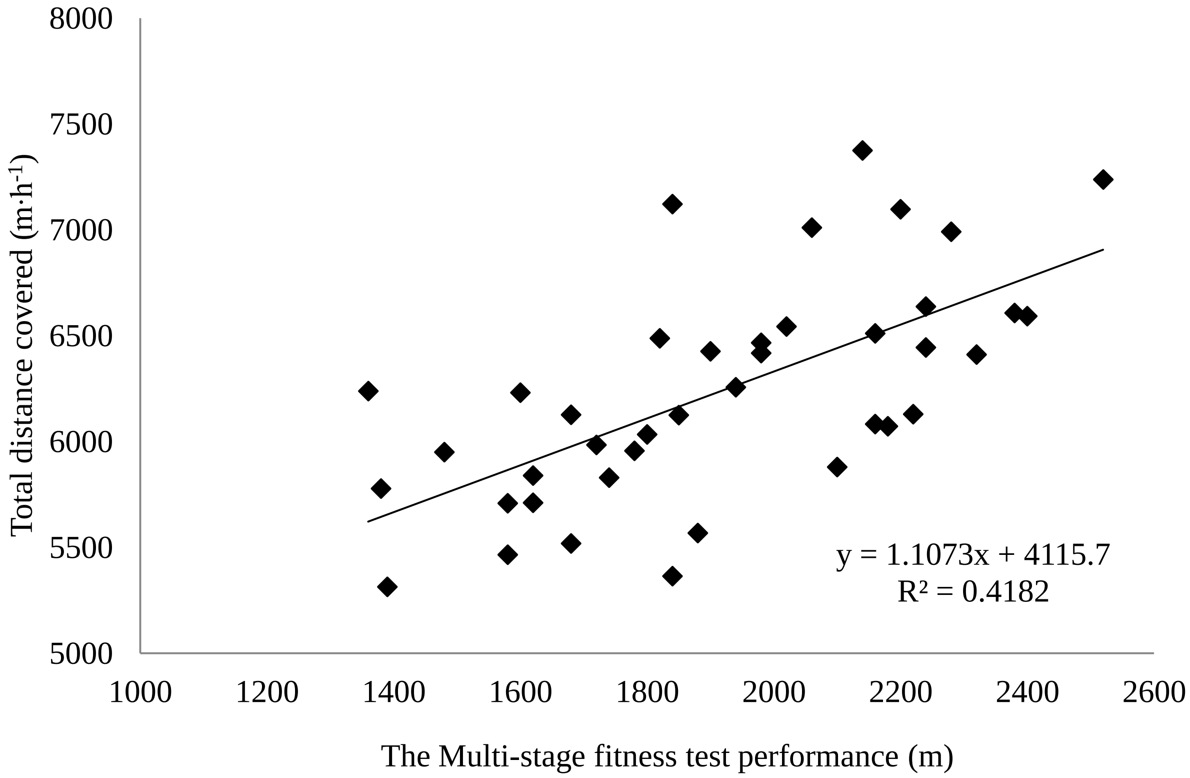


Figure 6.4 The relationship between the Multi-stage fitness test performance and total distance covered per hour of a match.

Multiple regression

Due to the relationship between chronological age and total distance covered per hour of a match and the percentage of time spent in moderate and high speed running, multiple regression was used to examine if, for the group as a whole, performance on the field tests made a further statistically significant contribution to the model above that contribution accounted for by chronological age.

Total distance covered per hour of a match

Chronological age accounted for 43% ($p < 0.01$) and the Multi-stage fitness test performance explained 7% ($p < 0.05$) of variance in total distance covered in an hour of a match (Table 6.2).

Table 6.2 Multiple regression and total distance covered per hour of a match with chronological age and the Multi-stage fitness test.

	B	Standard error	Beta	Significance
Step 1 (R^2 = 0.43)				
Constant	3611	500		$p < 0.01$
Chronological age	192	36	0.65	$p < 0.01$
Step 2 (R^2 = 0.50)				
Constant	3415	479		$p < 0.01$
Chronological age	116	47	0.39	$p < 0.05$
Multi-stage fitness test	0.65	0.28	0.38	$p < 0.05$

Percentage of time spent in moderate speed running

Chronological age ($p < 0.01$) and the Multi-stage fitness test performance ($p < 0.05$) accounted for 10% and 11% of variance in percentage of time spent in moderate speed running, respectively (Table 6.3).

Table 6.3 Multiple regression and percentage of time spent in moderate speed running with chronological age and the Multi-stage fitness test.

	B	Standard error	Beta	Significance
Step 1 (R^2 = 0.10)				
Constant	9.7	1.4		$p < 0.01$
Chronological age	-0.21	0.099	-0.32	$p < 0.05$
Step 2 (R^2 = 0.21)				
Constant	9.1	1.3		$p < 0.01$
Chronological age	-0.41	0.13	-0.63	$p < 0.01$
Multi-stage fitness test	0.002	0.001	0.46	$p < 0.05$

Percentage of time spent in high speed running

Chronological age accounted for 11% of the variance ($p < 0.01$) in the percentage of time spent in high speed running whereas 30 m sprint and the Multi-stage fitness test performances ($p < 0.05$ for both) explained for 15% and 8% of variance in percentage of time spent in high speed running, respectively (Table6.4).

Table 6.4 Multiple regression and percentage of time spent in high speed running with chronological age, 30 m sprint time and the Multi-stage fitness test.

	B	Standard error	Beta	Significance
Step 1 (R^2 = 0.11)				
Constant	4.7	0.93		$p < 0.01$
Chronological age	-0.15	0.67	-0.34	$p < 0.05$
Step 2 (R^2 = 0.26)				
Constant	14	3.5		$p < 0.01$
Chronological age	-0.36	0.099	-0.81	$p < 0.01$
30 m sprint	-1.4	0.50	-0.61	$p < 0.05$
Step 3 (R^2 = 0.34)				
Constant	12	3.5		$p < 0.01$
Chronological age	-0.44	0.10	-0.99	$p < 0.01$
30 m sprint	-1.1	0.50	-0.48	$p < 0.05$
Multi-stage fitness test	0.001	0.00	0.41	$p < 0.05$

6.3.2 U9 & U10 squads

<u>Field tests</u>

The mean sprint time (mean ± SD) at 5, 10, 15, 20 and 30 m were 1.15 ± 0.05 s, 2.03 ± 0.08 s, 2.88 ± 0.13 s, 3.68 ± 0.18 s and 5.29 ± 0.24 s, respectively. The mean completion time of the agility test was 4.82 ± 0.19 s for the Slalom agility test and 2.71 ± 0.09 s for the 505 agility test. For the standing vertical jumps, the mean scores were 25 ± 3 cm for the squat jump, 26 ± 3 cm for the counter movement jump without arms and 30 ± 4 cm for the counter movement jump with arms. Moreover, the mean of the Yo-Yo intermittent recovery test (level 1) performance was 722 ± 339 m and the mean from the Multi-stage fitness test performance was 1350 ± 294 m.

<u>Match performance</u>

The mean total distance covered per hour of a match was 4686 ± 354 $m \cdot h^{-1}$. The mean distance covered per hour of a match was 513 ± 133 $m \cdot h^{-1}$ for moderate speed running and 198 ± 60 $m \cdot h^{-1}$ for high speed running. The mean percentage of time spent during a match was 4.3 ± 1.1% for moderate speed running and 1.2 ± 0.4% for high speed running. The mean playing time was 52.7 ± 5.4 min in a match.

Relationship between field tests and match performance

Chronological age

Chronological age was significantly associated with the Yo-Yo intermittent recovery test (level 1) performance ($r = 0.43$, $p < 0.05$). Moreover, there was a relationship between chronological age and 10 m sprint time ($r = -0.40$, $p < 0.05$), 505 agility test performance ($r = -0.42$, $p < 0.05$) and performance from counter movement jump with arms ($r = 0.39$, $p < 0.05$). However, there were no statistically significant relationships between chronological age and high intensity match running performance.

Sprints

Sprint time measured at 20 m showed a significant positive relationship with distance covered per hour of a match by ($r = 0.54$, $p < 0.01$) and percentage time spent in ($r = 0.54$, $p < 0.01$) moderate speed running (figure 6.5). Five metre sprint time also showed a significant relationship with percentage of time spent in moderate speed running ($r = 0.40$, $p < 0.05$). No other significant relationships were found between sprint test and match performances.

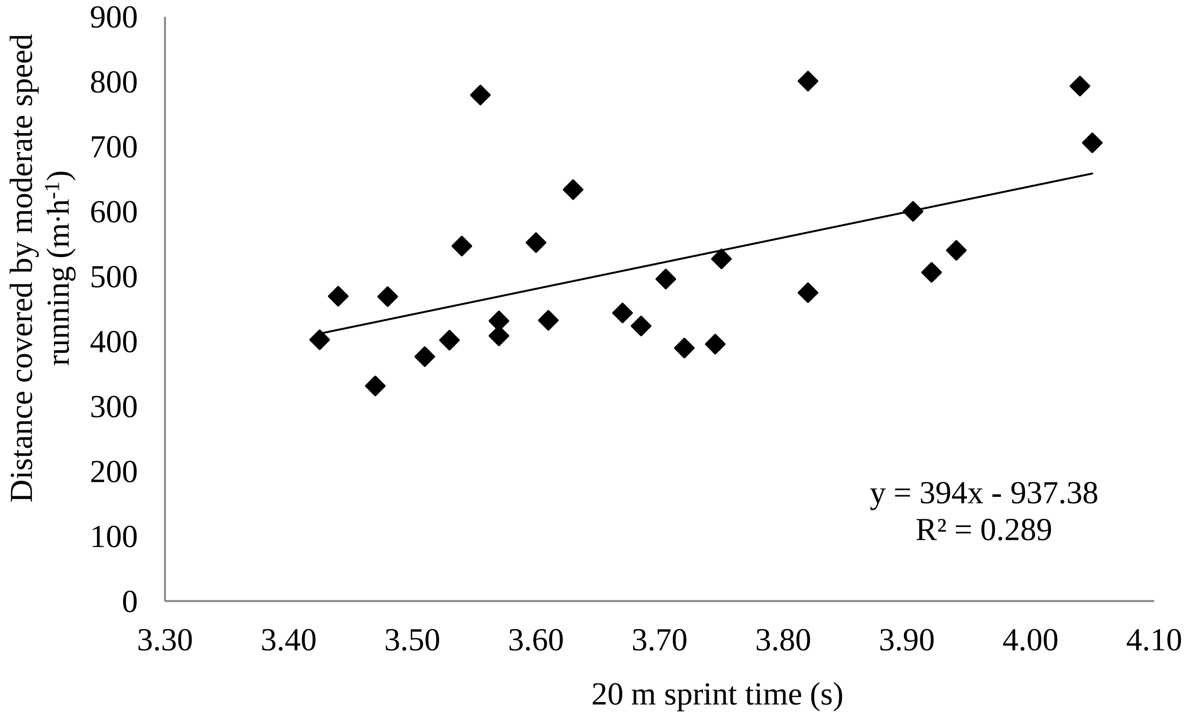


Figure 6.5 The relationship between 20 m sprint time and distance covered by moderate speed running per hour of a match.

Agility tests

The agility tests performances did not show any significant relationships with match running performance variables.

Standing vertical jumps

No other significant correlations were found between the standing vertical jump and match running performances.

Endurance tests

The performance from the Yo-Yo intermittent recovery test (level 1) and Multi-stage fitness test did not show any significant relationships with the match running performance variables.

6.3.3 U11-U13 squads

<u>Field tests</u>

The mean sprint time for the 5, 10, 15, 20 and 30 m were 1.09 ± 0.07 s, 1.90 ± 0.11 s, 2.64 ± 0.16 s, 3.37 ± 0.20 s and 4.81 ± 0.29 s, respectively. For the Slalom and 505 agility tests, the mean completion times were 4.43 ± 0.18 s and 2.53 ± 0.09 s, respectively. Performance during the standing vertical jumps was 31 ± 4 cm for the squat jump, 33 ± 5 cm for the counter movement jump without arms and 37 ± 5 cm for the counter movement jump with arms. Moreover, the distance covered during the Yo-Yo intermittent recovery test (level 1) and Multi-stage fitness test was 1358 ± 311 m and 1727 ± 210 m, respectively.

<u>Match performance</u>

The mean total distance covered per hour of a match was 5900 ± 359 $m \cdot h^{-1}$. The mean distance covered per hour of a match was 956 ± 129 $m \cdot h^{-1}$ for moderate speed running and 519 ± 176 $m \cdot h^{-1}$ for high speed running. The mean percentage of time spent in different speed zones during a match was 7.3 ± 1.0% for moderate speed running and 2.9 ± 0.9% for high speed running. The mean playing time was 61.3 ± 10.2 min in a match.

Relationship between field tests and match performance

Chronological age

Chronological age was significantly associated with sprint times at 10 ($r = -0.48, p < 0.05$), 15 ($r = -0.47, p < 0.05$), 20 ($r = -0.45, p < 0.05$) and 30 ($r = -0.45, p < 0.05$) m. No other significant relationships were detected between chronological age and field test performance and there was no relationship between chronological age and high intensity match running performance.

Sprints

Sprint time at 10, 15, 20 and 30 m showed a significant negative relationship with the total distance covered per hour of a match ($r = -0.59$ to -0.50, $p < 0.01$ for all: figure 6.6). Moreover, sprint time at 5, 10, 15, 20 and 30 m illustrated a significant negative relationship with distance covered per hour of a match by ($r = -0.67$ to -0.61, $p < 0.01$ for all) and percentage of time spent in ($r = -0.61$ to -0.46, $p < 0.01$) moderate speed running. No other relationships were shown between sprint times and match running performances.

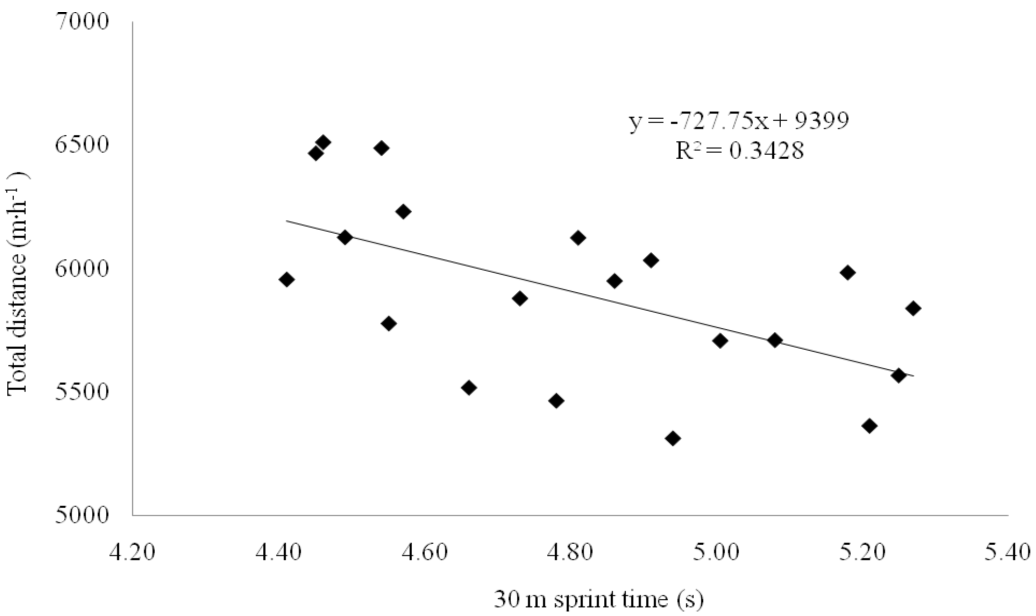


Figure 6.6 Relationship between 30 m sprint time and total distance covered per hour of a match.

Agility tests

No significant relationships were shown between both the Slalom and 505 agility tests and any of the match performance variables.

Standing vertical jumps

All standing vertical jumps (squat jump, counter movement jump without arms and counter movement jump with arms) showed a significant positive relationship with total distance covered per hour of a match ($r = 0.46$ to 0.62, $p < 0.01$ for all: figure 6.7) as well as distance covered per hour of a match by moderate speed running ($r = 0.62$ to 0.73, $p < 0.01$ for all). Moreover, all standing vertical jumps demonstrated a significant positive relationship with percentage of time spent in moderate speed running during a match ($r = 0.56$ to 0.68, $p < 0.01$ for all: figure 6.8). Furthermore, performance during the counter movement jump without arms illustrated a significant positive relationship with distance covered by ($r = 0.47$, $p < 0.01$) and percentage of time spent ($r = 0.46$, $p < 0.01$) in high speed running. There were no other significant relationships found between standing vertical jump performances and match running performances.

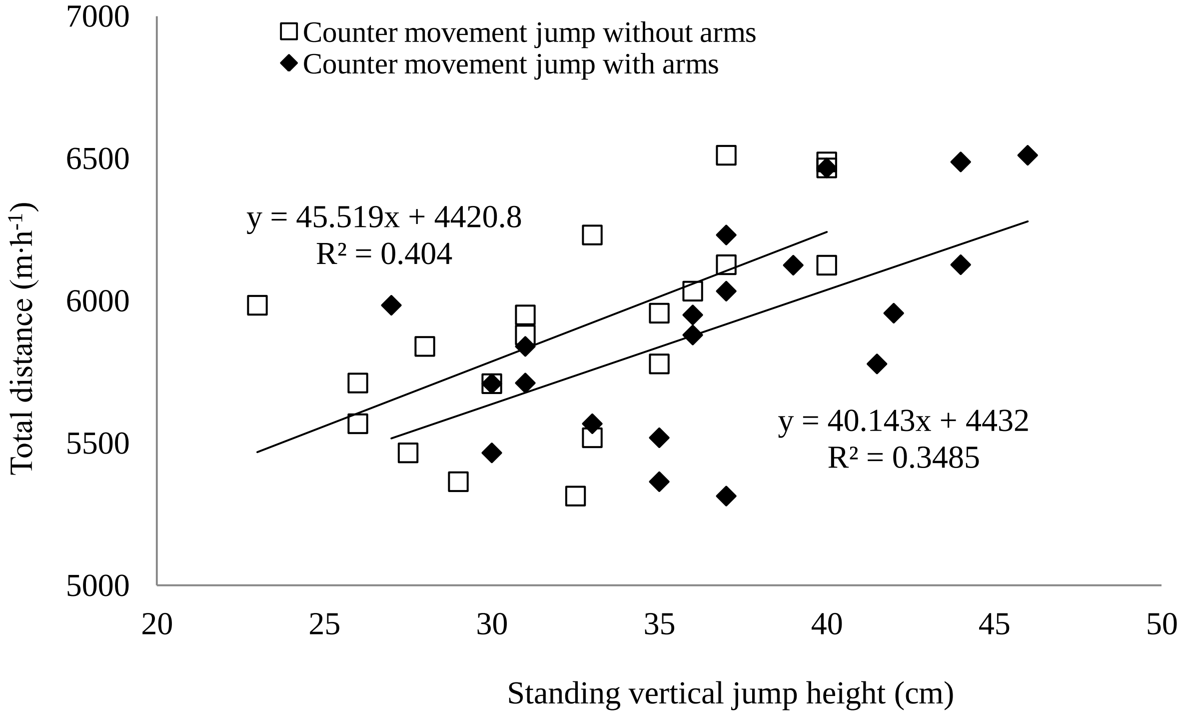


Figure 6.7 The relationship between performance during a counter movement jump without and with arms and total distance covered per hour of a match.

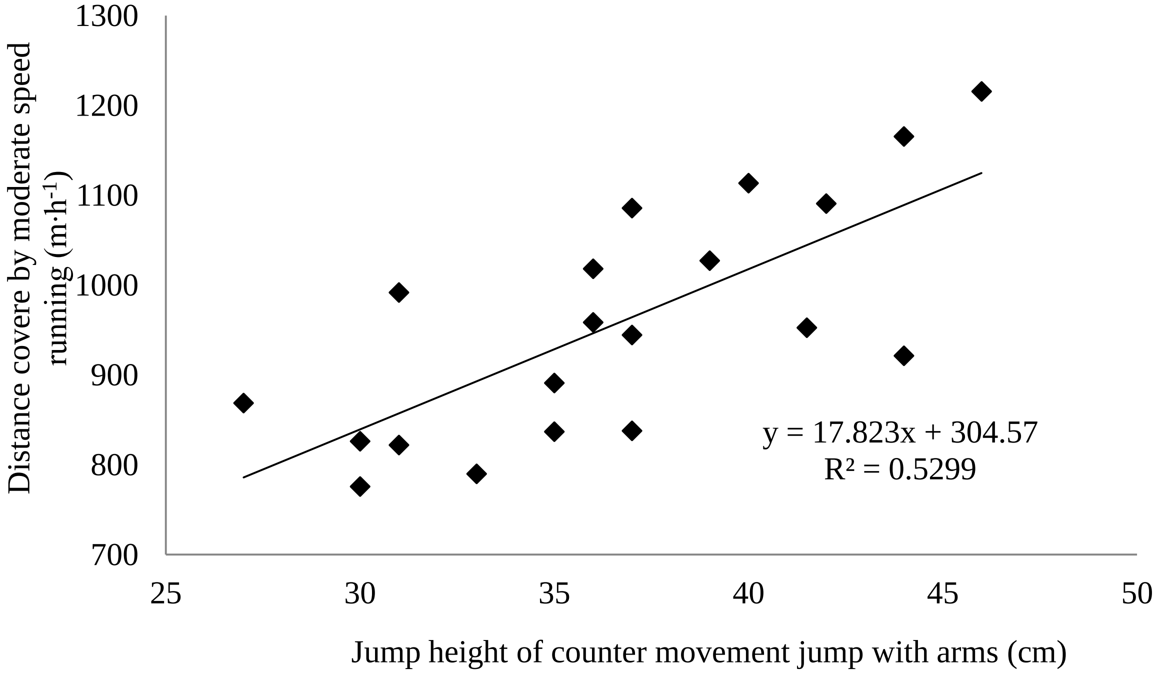


Figure 6.8 The relationship between performance during a counter movement jump with arms and distance covered by moderate speed running per hour of a match.

Endurance tests

The Yo-Yo intermittent recovery test (level 1) performance showed a significant relationships with the total distance covered per hour of a match ($r = 0.49$, $p < 0.05$), distance covered by high speed running per hour of a match ($r = 0.54$, $p < 0.05$, figure 6.9) and the percentage of time spent in moderate ($r = 0.45$, $p < 0.05$) and high ($r = 0.60$, $p < 0.01$) speed running. The Multi-stage fitness test performance was significantly associated with distance covered by moderate ($r = 0.51$, $p < 0.05$) and high ($r = 0.47$, $p < 0.05$) speed running per hour of a match and the percentage time spent in moderate ($r = 0.54$, $p < 0.05$) and high ($r = 0.52$, $p < 0.05$) speed running during a match. No other significant relationships were found between the endurance tests and match performance.

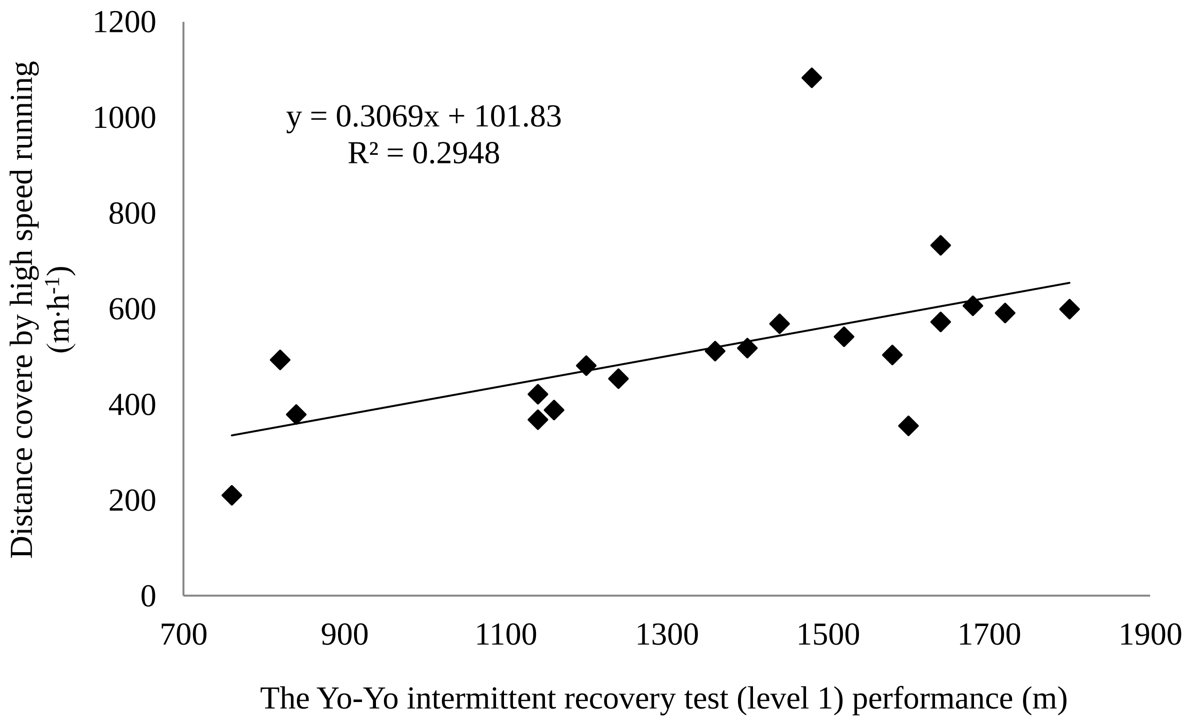


Figure 6.9 The relationship between the Yo-Yo intermittent recovery test (level 1) performance and distance covered by high speed running per hour of a match.

6.3.4 U14 - U16 squads

Field tests

The mean sprint times (mean ± SD) were 1.01 ± 0.05 s for 5 m, 1.75 ± 0.07 s for 10 m, 2.43 ± 0.09 s for 15 m, 3.07 ± 0.12 s for 20 m and 4.30 ± 0.19 s for 30 m. The mean completion times of agility tests were 4.20 ± 0.14 s for the Slalom agility test and 2.32 ± 0.07 s for the 505 agility test. The mean of standing vertical jump test performance was 35 ± 5 cm for squat jump, 36 ± 5 cm for counter movement jump without arms and 43 ± 5 cm for counter movement jump with arms. The distance covered during the Yo-Yo intermittent recovery test (level 1) and Multi-stage fitness test were 2202 ± 352 m and 2155 ± 181 m, respectively.

Match performance

The mean total distance covered per hour of a match was 6609 ± 404 $m{\cdot}h^{-1}$. The mean distance covered per hour of a match was 962 ± 191 $m{\cdot}h^{-1}$ for moderate speed running and 496 ± 111 $m{\cdot}h^{-1}$ for high speed running. The mean percentage of time spent during moderate speed running and high speed running were 6.5 ± 1.3% and 2.4 ± 0.5% during a match, respectively. The mean playing time was 66.7 ± 12.1 min in a match.

Relationship between field tests and match performance

Chronological age

Chronological age showed a significant relationship with the performance from 30 m sprint ($r = -0.48$, $p < 0.05$), the 505 agility test ($r = -0.48$, $p < 0.05$), the Yo-Yo intermittent recovery test (level 1) ($r = 0.67$, $p < 0.01$) and the Multi-stage fitness test ($r = 0.73$, $p < 0.01$). No other significant relationships were found between chronological age and, field tests and match performance variables.

Sprints

There were no significant relationships found between sprint times and match running performance variables.

Agility tests

The performance from the agility tests showed no significant relationships with any of the match running performance variables.

Standing vertical jumps

No significant relationships were found between standing vertical jump performance and any of the match running performance variables.

Endurance tests

The performance from endurance tests showed no significant relationships with any of the match running performance variables.

6.4 Discussion

The key finding of the present study was that when considering the players as one group (age U11 to U16) there was a statistically significant relationship between the total distance run and performance on a range of field tests (sprint, agility, standing vertical jump and endurance). Chronological age made a major contribution to the total distance run and the percentage of time at moderate and high speeds in the match. When this contribution of chronological age was accounted for using multiple regression the field tests still making a significant contribution to explaining the variance in match performance were the multi-stage fitness test and 30 m sprint performance. When the players were separated into 3 groups with a small age range (U9-U10, U11-U13 and U14-U16) the relationship between field test and match performance was similar in the U11-U13 age group to the whole group, but there were no such relationships for the U14-U16 group and in the U9-U10 group those sprinting the fastest covered the shortest distance in match play which was an opposite finding to the group as a whole.

Taking the group as a whole (U11-U16 squads), there were statistically significant relationships between field test sprint performance, agility, standing vertical jumps and endurance tests and distance run during a match. These findings are consistent with a study of professional adult soccer players (Krustrup et al., 2003) and U14 elite soccer players from San Marino (Castagna et al., 2009) where statistically significant relationships were shown between total distance covered during a match and performance during the Yo-Yo intermittent recovery test (level 1). Such relationships between the Yo-Yo intermittent recovery test (level 1) results and match distance run may exist because the intermittent activity pattern in the test is similar to that of a soccer match (Bangsbo et al., 2008). Overall, the relationship between distance run in a match and several field test results would suggest that simply the better the all-round athlete (as reflected by performance on the field tests) the greater the distance run in a match. However, the wide spread of chronological ages in the whole group (age 11-16) in the present study could also mean that older athletes are performing better both on the field tests and in terms of match distance run. The finding that there was no relationship between counter movement jump with arms and high intensity match running performances in an earlier study in elite professional soccer players (Rampinini et al, 2007a) adds some weight to this suggestion.

To account for this possible influence of age when examining the whole group, multiple regression was employed to examine which field tests contributed to explaining high intensity match running performances in addition to the effect of age. Using multiple regression analysis, the Multi-stage fitness test accounted for 7% of the variance in total distance covered per hour of a match and 11% of the variance in the percentage of time spent in moderate speed running during a match in the U11-U16 elite soccer players independent of chronological age (which accounted for 43% and 10% of variance, respectively). The Multi-stage fitness test estimates peak oxygen uptake (Ramsbottom et al., 1988) and soccer is mainly dependent upon aerobic metabolism as the players normally sustain between 80-90% of maximum heart rate through a match (Stolen et al., 2005). Therefore, this outcome was expected.

Furthermore, independent of chronological age (which accounted for 11% of variance), 15% and 8% of the variances in the percentage of time spent in high speed running during a match were explained by performance during the 30 m sprint and the Multi-stage fitness tests, respectively in the U11-U16 squads. Perhaps unexpectedly the faster the 30 m sprint performance, the lower the percentage of time spent in high speed running. This is possibly because the players learn the tactical elements with age and start to know when to, and when not to, perform high speed running. Another possible reason is an increased necessity of recovery time for those performers who are the fastest as it has been previously shown that recovery after sprinting is negatively related to top speed (Bogdanis et al., 1995). Moreover, during a soccer match, the players need a period of low intensity activity to recover from high intensity exercises (Stolen et al., 2005) and it has been suggested that a high level of endurance ability (60 $ml \cdot kg^{-1} \cdot min^{-1}$ as a minimum level of estimated peak oxygen uptake) is required in elite professional soccer players (Odetoyinbo and Ramsbottom, 1997). Therefore, the Multi-stage fitness test performance was also expected to account for some of the variance of percentage of time spent in high speed running. Thus the 30 m sprint and the Multi-stage fitness tests are useful field tests to predict total distance covered per hour of a match and the percentage of time spent in moderate and high speed running during a match in elite youth soccer players.

When the squads were separated, faster players in the U11-U13 age group over 10, 15, 20 and 30 m covered a greater total distance per hour and covered a longer distance and spent a higher percentage of time undertaking moderate speed running during a match. This is possibly because the players with the faster sprint test performance were running at a lower relative speed compared to the players with slower sprint test performance when they ran at the same speed in the match. Hence, the players with faster sprint test performance showed better moderate speed running performances. Moreover, as the total distance covered during a match will include the distance covered by moderate speed running, when the distance covered by moderate speed running is related to sprint test performance, the total distance covered is likely to be related to sprint test performance. Therefore, the 10-30 m sprint test is a useful field test to indicate total distance covered and the moderate speed running performance of the U11-U13 elite youth soccer players.

In the U11-U13 squads, there was also a significant positive relationship between the 3 standing vertical jumps and total distance covered per hour of a match, distance covered per hour by, and the percentage of time spent in moderate speed running during a match. Moreover, there was a significant positive relationship between the counter movement jump without arms and the distance covered per hour by, and the percentage of time spent in high speed running during a match. These are similar outcomes to when the relationship between sprint test and high intensity match running performances was examined. This might be expected as sprint and standing vertical jump performances are highly related (Wisloff et al., 1998). Moreover, it has been suggested that ability to perform an explosive generation of power and velocity when sprinting is functionally similar to the ability to perform a rapid explosive generation of power during jumping (Hansen et al., 2011). Therefore, the standing vertical jump is a useful field test which reflects the high intensity match running performance in the U11-U13 age group. This finding suggests that if a sprint test cannot be performed due to the unavailability of facilities or equipment, the standing vertical jump test can be conducted to gain information which will relate to high intensity match running performance.

For the U11-U13 squad there was a significant positive relationship between the Yo-Yo intermittent recovery test (level 1) performance and total distance covered during a match, distance covered per hour of a match by high speed running and the percentage of time spent in moderate and high speed running. Similarly, there was a significant positive relationship between the Multi-stage fitness test and the distance covered per hour by, and percentage of time spent in, moderate speed running and high speed running in the U11-U13 squads. These findings are consistent with those for the whole squad (age 11-16) and confirm that in players of this age (11-13 years old) good endurance performance (as reflected by the Yo-Yo intermittent recovery test (level 1) or Multi-stage fitness test) will result in greater match distances being covered. Thus, work rate in a match is not solely dependent on the match situation and on the movement of the ball and opponents, but also depends on the endurance capability of individual players. Therefore, the Yo-Yo intermittent recovery test (level 1) and Multi-stage fitness test performances are useful indicators of high intensity match running performance in the U11-U13 squads from the English Premier League Academy.

There were no significant relationships between field test and high intensity match running performances in the U14-U16 squads. One possible reason for this lack of relationship in this age group is the smaller range of performances compared to the range for players in other groups. For example the standard deviation of 30 m sprint test performance was 0.24, 0.29 and 0.19 s for the U9-U10 squads, U11-U13 squads and U14-U16 squads, respectively. However, it could also be that the players still with the academy at this age (who were high level players on contracts) had reached an adequate level of performance on the field tests for endurance, speed and power not to be limiting factors in the distances and speeds covered during match play.

When the squads were separated, in the U9 and U10 group, players with a faster sprint performance covered a shorter distance per hour by, and spent a less percentage of time in, moderate speed running during a match. This result is in conflict with the 11-16 year old and 11-13 year old groups where players with the fastest speeds, covered the greatest distances. The reason for this difference with the U9 and U10 squads is not known, but it might be partly due to difference in the area per player as the area per player for the U9 and U10 matches (97.1 m^2) was only half or less than that of the U11-U16 matches (193.5-312.5 m^2). The differences are unlikely to be due to the variance in the number of players per team because player number has been reported not to influence the distance covered as long as area per player is the same (Hill-Haas et al., 2009).

In the U9-U10 squads, there were no other significant relationships detected between field test results and high intensity match running performances. One reason for the lack of any relationship may be the variation in co-ordination in boys of this age resulting in for example poor jumping technique so that the field tests may not reflect power and endurance to the extent that they do in older boys (Roberton and Halverson, 1988). The lack of relationship between the Yo-Yo intermittent recovery test (level 1) and high intensity match running performance may also be because the running distance in each shuttle of the test is too long for the U9 and U10 players considering their pitch dimension (44.8 x 26 m). The length of their pitch (44.8 m) is almost as long as the distance they run in each shuttle (20 m x 2) and the players are not likely to continuously run 40 m at a high speed on many occasions during a match as an average high speed running distance is 29 m, even for the elite professional soccer players (Mohr et al., 2003). Therefore, field test performance may not always predict high intensity match running performance in the U9 and U10 squads from the English Premier League Academy.

In terms of the best tests for predicting high intensity match performance for the group as a whole (U11-U16) and for the separate groups of players (U9 and U10, U11-13, U14-U16), the sprint tests and multi-stage fitness test were the best predictors of high intensity match running performance. So for the whole group, the faster the 30 m sprint test performance the greater the high intensity match distances covered and the better the performance on the Multi-stage fitness test the greater the high intensity match running performance. When the players were separated down into the squad groups (U9 and U10, U11-U13, U14-U16) sometimes the relationship was better with another sprint distance or the relationship was lost. So, for example, with the U9 and U10 squads the 20 m sprint distance became the best predictor of high intensity match performance and the relationship between sprint and high intensity match distance no longer existed in the U14-U16 squads. Similarly with the Multi-stage fitness test within the smaller groups, the relationship between the Multi-stage fitness test performance and high intensity match distance run only remained for the U11-U13 group. These variations when the players were split into smaller groups were most likely to be due to the smaller number of players in each group and the very similar sprint and the Multi-stage fitness test performance amongst the players, so at present, while it would be advantageous to expand this work to include a larger number of players, it is safest to conclude that the best predictors of high intensity match distance run for a wide age range of players within the academy are the 30 m sprint test and the Multi-stage fitness test.

It is interesting that the Multi-stage fitness test was shown to be a better predictor of total distance covered during a match and high intensity match running performance than the Yo-Yo intermittent recovery test (level 1). In senior soccer players, the Multi-stage fitness test has been shown not to distinguish standard of players and not sensitive to trainings (Edwards et al., 2003) whereas the Yo-Yo intermittent recovery test (level 1) has been shown to possess a strong relationship with high intensity match running performance (Krustrup et al., 2003). This difference in the most appropriate endurance test between youth and senior players is possibly due to a difference in physiological characteristics between children and adults. Children have been shown to possess a higher proportion of type I fibres (Oertel, 1988; Lexell et al., 1992), to store less phosphocreatine (Eriksson and Saltin, 1974) and to have a higher oxidative enzyme activity (Haralambie, 1982) than adults. Hence, children potentially favour continuous type endurance exercise (the Multi-stage fitness test) rather than intermittent type endurance exercise (the Yo-Yo intermittent recovery test (level 1)) which includes high intensity activities in between low intensity activities and resting. Therefore, the Yo-Yo intermittent recovery test (level 1) may be a more suitable field test than the Multi-stage fitness test to predict high intensity match running performance from possibly the U17 or older age group, but until then, and thus in younger players the Multi-stage fitness test is a better predictor of the high intensity match running performance than the Yo-Yo intermittent recovery test (level 1).

In conclusion, in 11-16 years old English Premier League Academy players, 30 m sprint performance and the distance run during the Multi-stage fitness test made a significant contribution to the variation in match performance over and above the variation accounted for by chronological age. Within a tighter age range of players (U11-U13s) there was also a significant relationship between match performance and a range of field tests results including sprints, jump and endurance tests. Thus, some field tests results are able to contribute to explaining the variation in match distances and match speeds in the English Premier League Academy players.

Chapter 7
Biological maturity and physical characteristics of elite youth soccer players

7.1 Introduction

Biological maturity is a well known factor influencing body size in adolescent boys (Malina, 1988; Yague and De La Fuente, 1998). Also for some sports such as swimming, tennis and athletics it has been shown that athletes in national age group squads are of advanced maturity (Baxter-Jones and Helms, 1996). However, there is remarkably little information available concerning the impact of biological maturity on the performance of elite youth soccer players.

There are different methods to assess biological maturity. For example, dental age (Malina et al., 2004a), secondary sexual maturation (Tanner, 1962), skeletal age (Malina et al., 2004a) and predicting chorological age at peak height velocity (PHV) (Malina, 1988; Mirwald et al., 2002). Dental age involves wide assessment techniques with a limited applicability (Malina et al., 2004a). Secondary sexual maturation can only be used for adolescents and while traditionally medical specialists have assessed sexual maturity, it is now common for the participants themselves to undertake the assessments due to ethical concerns. However, self-assessment has been reported to possess sufficient accuracy and reliability (Petersen et al., 1988). Skeletal maturity is generally accepted as the best method (Malina et al., 2004a). However, it is costly and requires specialised equipment and the use of radiation can raise health and safety issues. Moreover, chronological age at PHV can be predicted by taking a series of standing height measurements over years (Malina, 1988). Furthermore, measurements including standing height, sitting height, body mass and chronological age collected from a single session allow an estimation of chronological age at PHV and this method can include participants with a chronological age range of 7 to 18 years (Mirwald et al., 2002).

In elite youth soccer players, previous research has examined the influence of maturation on the *physical* characteristics of players such as height and body mass and has used various methods to assess biological maturation. In 11-12, 13-14 and 15-16 years old elite Portuguese soccer players, standing height increased with skeletal age (Malina et al., 2000). Moreover, a positive significant influence of maturity on the standing height of 13-15 years old elite Portuguese soccer players (Malina et al., 2004b) and the U12-U15 English Premier League Academy players (Hulse, 2010, unpublished) was found when stage of pubic hair development was employed to examine biological maturity. For body mass, a significant positive influence of biological maturity was reported in 11-12 and 13-14 years old elite Portuguese soccer players when skeletal age was employed to examine biological maturity (Malina et al., 2000). Furthermore, when sexual maturation was determined by stage of pubic hair development there was a significant positive influence on the body mass of 13-15 years old Portuguese elite soccer players (Malina et al., 2004b) and in U12-U16 English Premier League Academy players (Hulse, 2010, unpublished).

In terms of *performance*, early maturers demonstrated a significantly faster 30 m sprint performance in 13-15 years old Portuguese elite soccer players (Malina et al., 2004b), 20 m sprint performance in the U11, U12 and U13 age groups (Hulse, 2010, unpublished) and, 10 m sprint performance in the U13 age group (Hulse, 2010, unpublished) compared to the later maturing counterparts when stage of pubic hair development was employed to assess biological maturity. For the standing vertical jumps, early maturers showed a significantly higher jump height than late maturers in U12, U13, U15 and U16 English Premier League Academy players (Hulse, 2010, unpublished) and in 13-15 year old Portuguese elite soccer players (Malina et al., 2004b) when stage of pubic hair development was employed to assess biological maturity. Moreover, in 13-15 year old Portuguese elite soccer players there was a positive influence of biological maturity on performance during the Yo-Yo intermittent endurance test (level 1) when stage of pubic hair development (Tanner, 1962) was employed to assess maturity (Malina et al., 2004b).

Thus, the effect of maturity on the physical characteristics and performance of some groups of elite youth soccer players has been examined. However, only a small range of performance tests have been employed and only a limited number of age groups have been assessed in these studies. Therefore, the influence of biological maturity on a larger variety of physical performance tests in elite youth soccer players with a wider range of age groups is required.

In addition, only a single method to assess biological maturity was employed in each of above studies. No studies in elite youth soccer players have examined biological maturation using more than one method to determine maturity.

The aim of the present study was to examine the influence of biological maturity on the physical characteristics and on a wide range of performance variables in elite youth soccer players with an age range of 8 to 18 years old. In this study, three methods of biological maturity assessment were used to confirm the influence of biological maturity on physical characteristics in elite youth soccer players. It was hypothesised that advanced biological maturity would result in physical and performance advantages in all age groups regardless of the method used to determine maturity.

7.2 Methods

7.2.1 Participants

The participants were 162 Premier League Academy players from a club in the East Midlands and their chronological age ranged from 8.5 to 18.2 years. Each age group formed a squad from the U9 to U18. The U9-U14 squads had 3 training sessions a week, the U15 and U16 squads had 4 training sessions a week and the U17 and U18 squads had six training sessions a week. All squads had an average of one match per week during the season. Players were provided with a written and verbal explanation of the study including all tests and measurements to be taken. Each player signed an informed consent form and completed a health screen questionnaire prior to participation in the study. Players' parents, guardians or care-givers signed the consent form prior to the start of the study. Participants were withdrawn from a particular test if they did not have a satisfactory health status. The study was approved by Loughborough University Ethical Committee.

7.2.2 Measurements

Anthropometry was measured as described in Chapter 3 and this included standing height, sitting height, body mass and skinfolds. The field tests used were as described in Chapter 3. In brief, the field tests were a 30 m sprint with split times at 5, 10, 15 and 20 m, the Slalom agility test, the 505 agility test (Draper and Lancaster, 1985), a squat jump, counter movement jump without arms and counter movement jump with arms, the Yo-Yo intermittent recovery test level 1 (Bangsbo, 2005) and the Multi-stage fitness test (Ramsbottom et al., 1988).

7.2.3 Assessment of biological maturity

Biological maturity was assessed as described in Chapter 3. Briefly, stage of genital development (Tanner, 1962) and stage of pubic hair development (Tanner, 1962) were self-assessed by the players using photographs of secondary sexual development. Estimated chronological age at PHV was determined using chronological age, standing height, sitting height and body mass (Mirwald et al., 2002). Stage of genital development and stage of pubic hair development (Tanner, 1962) were employed to assess the biological maturity of the U12, U13 and U14 squads. Only the U12, U13 and U14 squads were assessed as most variations in sexual maturation were observed in these age groups in English Premier League Academy players (Hulse, 2010, unpublished) and it was challenging to obtain parental consent and player assent for this procedure. Therefore, this assessment was completed only where it was expected there would be a large variance in the ratings within an age group. Estimated chronological age at PHV (Mirwald et al., 2002) was used to assess biological maturity of the whole group (U9-U18 squads). The players from each squad (e.g., U10s) were separated into two groups based on their estimated chronological age at PHV (earlier maturers and later maturers). Then to ensure a large enough number of participants in each group for statistical analyses, the players were grouped as follows: U9/U10s, U11/U12s, U13/U14s, U15/U16s and U17/U18s.

7.2.4 Statistical analyses

Statistical analysis was conducted separately on the U12, U13 and U14 squads when biological maturity was assessed using stage of genital development (G, stage 3 = G3) and stage of pubic hair development (PH, stage 3 = PH3), but as combined groups (U9/U10s, U11/U12s, U13/U14s, U15/U16s and U17/U18s) when estimated chronological age at PHV was used as the method for determining maturity. Statistical tests were conducted when there were at least five participants. One way analysis of variance with a Tukey post hoc test was used to compare three or more groups and an independent sample t-test was used to compare 2 groups. Results are presented as mean ± standard deviation (SD) and PASW 18.0 was used for all the statistical analyses. In tables, stage of genital development and stage of pubic hair development are expressed as G and PH, respectively (eg., stage 3 of genital development = G3). Goalkeepers were excluded from all statistical analysis and data presented.

7.3. Results

7.3.1 Stage of genital development, physical characteristics and field test performance of the U12, U13 and U14 squads

Most of the U12 players were at Tanner stage 3 of genital development (45%). Standing height increased with genital stage ($p < 0.05$) with almost a 10 cm difference and 8 cm difference respectively between stage 1 ($p < 0.01$) and 2 ($p < 0.05$) and stage 4. Similarly, body mass increased with genital stage ($p < 0.05$). Maturity, as measured by genital stage did not impact on field test performance (table 7.1).

Most of the U13 players were at Tanner genital stage 3 (39%) or 4 (32%). Standing height and body mass increased with genital stage ($p < 0.05$ for both). The players in stage 5 were 9 cm taller and 9 kg heavier than the players in stage 3 ($p < 0.05$ for both). There was a tendency for the players in stage 5 of genital development to be faster than the players in stage 3 in 30 m sprint ($p = 0.088$) and performance during the counter movement jump without arms to be influenced ($p = 0.115$). Both the counter movement jump with arms and the Multi-stage fitness test performances increased with genital stage ($p < 0.05$ for both). The players in stage 4 jumped 5 cm higher than the players in stage 3 ($p < 0.05$). Moreover, the U13 players in stage 5 covered around 300 m longer than the players in stage 4 during the Multi-stage fitness test ($p < 0.05$) (table 7.2).

In the U14 squad, stage 4 contained the most players (64%). Standing height and body mass increased with genital stage ($p < 0.05$ for both) with approximately a 10 cm difference in standing height and almost a 12 kg difference in body mass between the players in stage 3 and 5. Biological maturity examined by stage of genital development showed no significant influences on field test performance (table 7.3).

Table 7.1 Stage of genital development and physical characteristics of the U12 players.

		1	2	3	4	5	
N		6	7	17	7	1	
Chronological age (years)	Mean	12.0	11.7	12.0	12.0	12.4	
	SD	0.3	0.3	0.4	0.2		
Standing height (cm)	Mean	147.8**	150.2*	154.2	158.1	171.1	aa
	SD	5.0	5.2	5.2	4.4		
Body mass (kg)	Mean	39.6	39.6	44.5	47.3	54.9	a
	SD	3.1	3.8	5.8	6.4		
Sum of 4 skinfold sites (mm)	Mean	28.0	30.1	34.0	28.5	29.6	
	SD	7.7	8.4	13.0	4.5		
Estimated body fat composition (%)	Mean	12.4	13.3	14.2	12.6	13.5	
	SD	3.1	3.6	4.6	2.3		
Sprints (s)							
5 m	Mean	1.09	1.11	1.07	1.05	1.04	
	SD	0.06	0.04	0.06	0.05		
10 m	Mean	1.91	1.93	1.87	1.85	1.83	
	SD	0.09	0.09	0.09	0.07		
15 m	Mean	2.66	2.71	2.63	2.57	2.55	
	SD	0.13	0.13	0.11	0.11		
20 m	Mean	3.41	3.45	3.36	3.28	3.26	
	SD	0.17	0.18	0.14	0.14		
30 m	Mean	4.82	4.92	4.79	4.67	4.74	
	SD	0.21	0.27	0.21	0.25 (N = 6)		

$^{a}p < 0.05$, $^{aa}p < 0.01$ significant effect of maturity.
*p < 0.05, **p < 0.01 significantly different to G4.

Table 7.1 (continued) Stage of genital development and physical characteristics of the U12 players.

		1	2	3	4	5
N		6	7	17	7	1
Slalom agility test (s)	Mean SD	4.54 0.21	4.47 0.07	4.59 0.22	4.44 0.14	4.55
505 agility test (s)	Mean SD	2.54 0.08	2.52 0.11	2.55 0.11 (N = 16)	2.54 0.07	2.62
Squat jump (cm)	Mean SD	30 3	27 3	30 4	31 4	34
Counter movement jump without arms (cm)	Mean SD	31 3	30 5	31 4	33 4	36
Counter movement jump with arms (cm)	Mean SD	35 5	33 4	33 5	37 4	39
The Yo-Yo intermittent recovery test (m)	Mean SD	1080 357	1027 234 (N = 6)	978 355 (N = 16)	1213 277 (N = 6)	1120
The Multi-stage fitness test (m)	Mean SD	1750 257	1637 178	1514 202 (N = 16)	1697 315	1400

Chronological age was 12.0 ± 0.3 years for 505 agility test in G4 and 11.6 ± 0.3 years for the Yo-Yo intermittent recovery test in G2.

Table 7.2 Stage of genital development and physical characteristics of the U13 players.

		2	3	4	5	
N		3	12	10	6	
Chronological age (years)	Mean	13.0	13.0	13.0	12.8	
	SD	0.3	0.4	0.4	0.3	
Standing height (cm)	Mean	160.1	159.1	162.6	168.1[#]	a
	SD	5.2	6.3	7.4	4.1	
Body mass (kg)	Mean	57.0	46.2	50.8	55.2[#]	a
	SD	2.8	5.2	8.1	4.5	
Sum of 4 skinfold sites (mm)	Mean	51.1	27.4	27.1	26.8	
	SD	26.6	8.3	6.4	6.0	
Estimated body fat composition (%)	Mean	18.0	12.4	12.2	11.8	
	SD	9.8	4.0	2.5	3.7	
Sprints (s)						
5 m	Mean	1.06	1.06	1.06	1.01	
	SD	0.03	0.04	0.05	0.03	
10 m	Mean	1.89	1.86	1.83	1.77	
	SD	0.13	0.08	0.09	0.06	
15 m	Mean	2.61	2.60	2.55	2.49	
	SD	0.21	0.11	0.13	0.11	
20 m	Mean	3.30	3.32	3.25	3.15	
	SD	0.27	0.14	0.19	0.13	
30 m	Mean	4.73	4.73	4.59	4.47	
	SD	0.49	0.22	0.26	0.16	

[a]$p < 0.05$ significant effect of maturity.
[#]$p < 0.05$ significantly different to G3.

Table 7.2 (continued) Stage of genital development and physical characteristics of the U13 players.

		2	3	4	5	
N		3	12	10	6	
Slalom agility test (s)	Mean	4.43	4.39	4.39	4.35	
	SD	0.31	0.21	0.16	0.05	
505 agility test (s)	Mean	2.60	2.51	2.43	2.46	
	SD	0.16	0.18	0.07	0.11 (N = 5)	
Squat jump (cm)	Mean	25	31	34	34	
	SD	4	4	4	4	
Counter movement jump without arms (cm)	Mean	30	32	35	36	
	SD	3	4	4	4	
Counter movement jump with arms (cm)	Mean	33	36	41[#]	41	a
	SD	5	4	6	4	
The Yo-Yo intermittent recovery test (m)	Mean	1693	1277	1244	1507	
	SD	740	453	450	398	
The Multi-stage fitness test (m)	Mean	1807	1735	1654	2072*	a
	SD	413	314	241	264 (N = 5)	

[a]$p < 0.05$ significant effect of maturity.
[#]$p < 0.05$ significantly different to G3.
*$p < 0.05$ significantly different to G4.

Table 7.3 Stage of genital development and physical characteristics of the U14 players.

		3	4	5	
N		5	23	8	
Chronological age (years)	Mean	14.0	14.0	14.0	
	SD	0.3	0.4	0.3	
Standing height (cm)	Mean	163.6	168.6	174.0[#]	a
	SD	4.2	7.0	4.4	
Body mass (kg)	Mean	50.8	55.5	62.7[#]	a
	SD	6.6	7.4	7.3	
Sum of 4 skinfold sites (mm)	Mean	27.4	28.4	27.9	
	SD	7.7	5.4	5.8	
			(N = 19)		
Estimated body fat composition (%)	Mean	12.0	12.6	12.4	
	SD	3.0	2.8	3.3	
			(N = 19)		
Sprints (s)					
5 m	Mean	1.03	1.02	1.05	
	SD	0.06	0.06	0.03	
10 m	Mean	1.81	1.77	1.81	
	SD	0.09	0.07	0.07	
15 m	Mean	2.53	2.48	2.50	
	SD	0.12	0.11	0.11	
20 m	Mean	3.20	3.14	3.16	
	SD	0.16	0.13	0.15	
30 m	Mean	4.56	4.45	4.42	
	SD	0.23	0.20	0.26	
			(N = 22)		

In G3, chronological age for sum of 4 skinfolds and estimated body fat was 14.1 ± 0.4 years.
[a]$p < 0.05$ significant effect of maturity.
[#]$p < 0.05$ significantly different to G3.

Table 7.3 (continued) Stage of genital development and physical characteristics of the U14 players.

		3	4	5
N		5	23	8
Slalom agility test (s)	Mean	4.29	4.30	4.33
	SD	0.17	0.18	0.15
			(N = 17)	
505 agility test (s)	Mean	2.43	2.42	2.38
	SD	0.14	0.07	0.07
			(N = 18)	
Squat jump (cm)	Mean	35	33	35
	SD	3	5	4
			(N = 21)	
Counter movement jump without arms (cm)	Mean	34	34	35
	SD	5	5	4
Counter movement jump with arms (cm)	Mean	38	40	41
	SD	5	7	5
The Yo-Yo intermittent recovery test (m)	Mean	1680	1598	1540
	SD	457	324	431
			(N = 19)	
The Multi-stage fitness test (m)	Mean	2050	1853	1894
	SD	254	216	214
		(N = 4)	(N = 15)	(N = 7)

In G3, chronological age for both agility tests and the Yo-Yo intermittent recovery test was 14.1 ± 0.4 years.

7.3.2 Stage of pubic hair development, physical characteristics and field test performance of the U12, U13 and U14 squads

Most of the U12 players were at Tanner stage 2 of pubic hair development (42%). Standing height increased with pubic hair stage ($p < 0.01$) with roughly a 7 cm difference between the players in stage 2 and 4 ($p < 0.05$). Similarly, Slalom agility test performance improved with stage of pubic hair development ($p < 0.05$) with almost 0.2 s difference between the players in stage 2 and 4 ($p < 0.05$). Moreover, there was a tendency for performance during counter movement jump with arms to be influenced by stage of pubic hair development ($p = 0.073$) and the players in stage 4 tended to perform better in counter movement jump with arms compared to the players in stage 2 ($p = 0.063$) (table 7.4).

Most of the U13 players were at Tanner pubic hair stage 4 (46%). Biological maturity examined by stage of pubic hair development showed no significant influences on height, body mass, sum of skinfolds and estimated body fat composition. However, performance during 5 m sprint test was tended to be faster in the players in stage 5 than stage 3 ($p = 0.054$). Moreover, there was a tendency for performance during counter movement jump without ($p = 0.118$) and with ($p = 0.113$) arms to be influenced by stage of pubic hair development. Furthermore, distance covered during the Multi-stage fitness test significantly improved with stage of pubic hair development ($p < 0.05$) (table 7.5).

In the U14 squad, most of the players were categorised as stage 4 of pubic hair development (47%). Standing height increased with stage of pubic hair development ($p < 0.01$) with almost a 8 cm difference and 11 cm difference, respectively between stage 3 and stage 4 ($p < 0.05$) and stage 5 ($p < 0.01$). Moreover, body mass increased with stage of pubic hair development ($p < 0.01$) and the players in stage 5 of pubic hair development were almost 13 kg heavier than the players in stage 3 ($p < 0.05$). Biological maturity examined by stage of pubic hair development showed no significant influences on field test performance (table 7.6).

Table 7.4 Stage of pubic hair development and physical characteristics of the U12 players.

		1	2	3	4	5	
N		2	16	10	8	2	
Chronological age (years)	Mean	12.0	11.9	12.0	11.9	12.4	
	SD	0.1	0.4	0.3	0.3	0.1	
Standing height (cm)	Mean	149.8	150.4*	153.5	157.5	167.6	aa
	SD	4.1	5.5	5.6	3.8	4.9	
Body mass (kg)	Mean	38.9	41.9	44.1	45.3	53.1	
	SD	1.3	4.4	7.8	5.7	2.5	
Sum of 4 skinfold sites (mm)	Mean	24.2	34.0	31.9	26.9	29.8	
	SD	7.2	10.6	12.7	5.7	0.2	
Estimated body fat composition (%)	Mean	10.8	14.9	13.1	11.7	12.9	
	SD	3.1	3.8	4.0	3.3	0.9	
Sprints (s)							
5 m	Mean	1.07	1.10	1.06	1.05	1.05	
	SD	0.05	0.05	0.06	0.06	0.01	
10 m	Mean	1.89	1.90	1.87	1.85	1.83	
	SD	0.05	0.09	0.10	0.07	0.01	
15 m	Mean	2.61	2.66	2.64	2.59	2.52	
	SD	0.11	0.11	0.14	0.11	0.04	
20 m	Mean	3.36	3.38	3.38	3.31	3.23	
	SD	0.13	0.14	0.18	0.15	0.04	
30 m	Mean	4.76	4.82	4.79	4.74	4.63	
	SD	0.14	0.24	0.26	0.24	0.16	
					(N = 7)		

In PH4, chronological age for sprints was 12.0 ± 0.3 years.
$^{aa}p < 0.01$ significant effect of maturity.
$^{*}p < 0.05$ significantly different to PH4.

Table 7.4 (continued) Stage of pubic hair development and physical characteristics of the U12 players.

		1	2	3	4	5	
N		2	16	10	8	2	
Slalom agility test (s)	Mean	4.42	4.68[#]	4.45	4.47	4.44	a
	SD	0.27	0.22	0.14	0.12 (N = 7)	0.14	
505 agility test (s)	Mean	2.55	2.56	2.49	2.59	2.53	
	SD	0.02	0.10	0.09	0.09 (N = 7)	0.13	
Squat jump (cm)	Mean	29	29	30	32	32	
	SD	5	4	5	3	4	
Counter movement jump without arms (cm)	Mean	32	30	30	34	35	
	SD	3	4	5	2	1	
Counter movement jump with arms (cm)	Mean	36	33	33	37	39	
	SD	1	4	4	5	1	
The Yo-Yo intermittent recovery test (m)	Mean	1220	957	1044	1166	1120	
	SD	594	241	359	385 (N = 7)	0	
The Multi-stage fitness test (m)	Mean	1770	1585	1532	1735	1470	
	SD	495	212	251	226	99	

In PH4, chronological age for the Yo-Yo intermittent recovery test was 12.0 ± 0.3 years.
[a] $p < 0.05$ significant effect of maturity.
[#] $p < 0.05$ significantly different to PH3.

Table 7.5 Stage of pubic hair development and physical characteristics of the U13 players.

		2	3	4	5
N		4	10	18	7
Chronological age (years)	Mean	12.9	12.8	13.1	12.9
	SD	0.3	0.4	0.4	0.2
Standing height (cm)	Mean	158.5	158.5	162.3	166.5
	SD	7.9	5.7	7.7	5.6
Body mass (kg)	Mean	48.5	46.8	52.3	54.1
	SD	6.4	6.1	8.6	5.1
Sum of 4 skinfold sites (mm)	Mean	38.0	33.2	29.7	26.9
	SD	25.5	14.9	13.1	4.6
		(N = 3)		(N = 17)	
Estimated body fat composition (%)	Mean	14.7	13.9	13.2	12.0
	SD	6.5	6.1	4.6	3.0
		(N = 3)		(N = 17)	
Sprints (s)					
5 m	Mean	1.04	1.08	1.05	1.02
	SD	0.04	0.04	0.06	0.04
10 m	Mean	1.86	1.88	1.82	1.79
	SD	0.11	0.09	0.11	0.07
15 m	Mean	2.58	2.63	2.54	2.52
	SD	0.13	0.14	0.15	0.10
20 m	Mean	3.30	3.34	3.25	3.19
	SD	0.16	0.17	0.21	0.12
30 m	Mean	4.66	4.75	4.61	4.53
	SD	0.28	0.28	0.29	0.16
				(N = 16)	

Table 7.5 (continued) Stage of pubic hair development and physical characteristics of the U13 players.

		2	3	4	5	
N		4	10	18	7	
Slalom agility test (s)	Mean	4.30	4.43	4.38	4.35	
	SD	0.25	0.19	0.22	0.08	
		(N = 3)		(N = 17)		
505 agility test (s)	Mean	2.50	2.55	2.47	2.45	
	SD	0.18	0.20	0.16	0.11	
		(N = 3)			(N = 6)	
Squat jump (cm)	Mean	33	30	32	34	
	SD	5	5	5	4	
		(N = 3)	(N = 8)	(N = 14)		
Counter movement jump without arms (cm)	Mean	34	31	34	36	
	SD	3	4	5	4	
Counter movement jump with arms (cm)	Mean	38	35	40	41	
	SD	4	5	8	3	
The Yo-Yo intermittent recovery test (m)	Mean	1280	1124	1438	1371	
	SD	435	571	434	271	
				(N = 16)		
The Multi-stage fitness test (m)	Mean	1800	1562	1834	1890	a
	SD	365	276	292	242	
		(N = 3)		(N = 16)	(N = 6)	

In PH3, chronological age was 12.9 ± 0.5 years for 505 agility tests and in PH5, chronological age was 12.9 ± 0.2 years for 505 agility tests and the Multi-stage fitness test.

[a]$p < 0.05$ significant effect of maturity.

Table 7.6 Stage of pubic hair development and physical characteristics of the U14 players**.**

		3	4	5	
N		8	18	12	
Chronological age (years)	Mean	13.7	14.1	14.0	
	SD	0.3	0.3	0.3	
Standing height (cm)	Mean	161.3	169.9#	172.0##	aa
	SD	5.0	5.9	5.9	
Body mass (kg)	Mean	49.0	55.7	61.5#	aa
	SD	5.8	7.1	6.9	
Sum of 4 skinfold sites (mm)	Mean	26.7	26.4	30.5	
	SD	6.8	5.8	4.9	
		(N = 7)	(N = 15)	(N = 11)	
Estimated body fat composition (%)	Mean	11.9	11.7	13.4	
	SD	2.6	3.0	2.9	
		(N = 7)	(N = 15)	(N = 11)	
Sprints (s)					
5 m	Mean	1.03	1.03	1.03	
	SD	0.04	0.06	0.04	
10 m	Mean	1.79	1.80	1.77	
	SD	0.06	0.08	0.06	
15 m	Mean	2.52	2.51	2.46	
	SD	0.07	0.12	0.10	
20 m	Mean	3.19	3.18	3.10	
	SD	0.12	0.15	0.12	
30 m	Mean	4.53	4.50	4.37	
	SD	0.17	0.22	0.21	
		(N = 6)			

aa $p < 0.01$ significant effect of maturity.
# $p < 0.05$, ## $p < 0.01$ significantly different to PH3.

Table 7.6 (continued) Stage of pubic hair development and physical characteristics of the U14 players.

		3	4	5
N		8	18	12
Slalom agility test (s)	Mean	4.29	4.31	4.32
	SD	0.14	0.18	0.16
		(N = 5)	(N = 15)	(N = 10)
505 agility test (s)	Mean	2.41	2.44	2.39
	SD	0.10	0.08	0.07
		(N = 5)	(N = 14)	
Squat jump (cm)	Mean	32	33	34
	SD	2	6	4
		(N = 6)		(N = 11)
Counter movement jump without arms (cm)	Mean	34	34	34
	SD	2	5	5
		(N = 7)		
Counter movement jump with arms (cm)	Mean	38	40	40
	SD	4	7	6
		(N = 7)		
The Yo-Yo intermittent recovery test (m)	Mean	1573	1565	1640
	SD	403	333	399
		(N = 6)	(N = 16)	(N = 11)
The Multi-stage fitness test (m)	Mean	1784	1887	1930
	SD	331	198	208
		(N = 5)	(N = 12)	(N = 10)

7.3.3 Estimated chronological age at PHV, physical characteristics and field test performance of the U9-U18 squads

U9/U10

There was a difference of 7 months in the estimated chronological age at PHV for the earlier and later maturing boys, but chronological age at the time of testing was the same. Body mass was significantly heavier for the earlier maturers ($p < 0.01$), but performance from counter movement jump without arms was significantly lower for the earlier maturers ($p < 0.05$). No other significant differences were detected in physical performance or characteristics between earlier and later maturing boys (table 7.7).

Table 7.7 Physical characteristics of earlier and later maturers from the U9 & U10 squads.

U9 & U10 squads		Earlier	Later
N		25	26
Chronological age (years)	Mean	9.4	9.4
	SD	0.6	0.6
Estimated chronological age at PHV (years)	Mean	12.9**	13.5
	SD	0.3	0.2
Standing height (cm)	Mean	140.7	138.5
	SD	5.2	5.3
Body mass (kg)	Mean	35.3**	32.2
	SD	3.9	3.9
Sum of 4 skinfold sites (mm)	Mean	30.4	26.0
	SD	9.1	7.5
Estimated body fat composition (%)	Mean	15.2	13.4
	SD	3.9	3.6

**$p < 0.01$ significantly different to later maturers.

Table 7.7 (continued) Physical characteristics of earlier and later maturers from the U9 & U10 squads.

			Earlier	Later
N			25	26
Sprints (s)				
	5 m	Mean	1.14	1.15
		SD	0.05	0.06
	10 m	Mean	2.03	2.03
		SD	0.07	0.09
	15 m	Mean	2.84	2.84
		SD	0.12	0.14
	20 m	Mean	3.66	3.64
		SD	0.14	0.19
	30 m	Mean	5.27	5.23
		SD	0.23	0.30
Slalom agility test (s)		Mean	4.93	4.86
		SD	0.19	0.24
505 agility test (s)		Mean	2.82	2.77
		SD	0.14	0.13
Squat jump (cm)		Mean	24	25
		SD	3	4
Counter movement jump without arms (cm)		Mean	25*	28
		SD	4	4
Counter movement jump with arms (cm)		Mean	28	30
		SD	3	4
The Yo-Yo intermittent recovery test (m)		Mean	592	557
		SD	227	273
The Multi-stage fitness test (m)		Mean	1270	1319
		SD	236	338

*$p < 0.05$ significantly different to later maturers.

U11/U12

There was a 6 months differences in estimated chronological age at PHV between the earlier and later maturing boys ($p < 0.01$), however, chronological age was the same when the measurements were taken. Earlier maturers were taller ($p < 0.01$), heavier ($p < 0.01$), had a thicker sum of 4 skinfold sites ($p < 0.01$) and a higher estimated body fat composition ($p < 0.01$) compared to the later maturers. There were no other significant differences in physical characteristics or performance between earlier and later maturing boys (table 7.8).

Table 7.8 Physical characteristics of earlier and later maturers from the U11 & U12 squads.

		Earlier	Later
N		19	19
Chronological age (years)	Mean	11.7	11.7
	SD	0.6	0.5
Estimated chronological age at PHV (years)	Mean	13.4**	13.9
	SD	0.3	0.2
Standing height (cm)	Mean	154.9**	149.3
	SD	7.0	4.8
Body mass (kg)	Mean	45.6**	39.6
	SD	7.0	3.6
Sum of 4 skinfold sites (mm)	Mean	35.4*	27.2
	SD	11.8	6.9
Estimated body fat composition (%)	Mean	16.0**	12.4
	SD	4.3	2.4

*p < 0.05, **p < 0.01 significantly different to later maturers.

Table 7.8 (continued) Physical characteristics of earlier and later maturers from the U11 & U12 squads.

			Earlier	Later
N			19	19
Sprints (s)				
	5 m	Mean	1.11	1.09
		SD	0.06	0.05
	10 m	Mean	1.94	1.91
		SD	0.11	0.08
	15 m	Mean	2.71	2.68
		SD	0.14	0.10
	20 m	Mean	3.46	3.41
		SD	0.18	0.14
	30 m	Mean	4.95	4.88
		SD	0.26	0.23
Slalom agility test (s)		Mean	4.56	4.61
		SD	0.20	0.21
505 agility test (s)		Mean	2.65	2.64
		SD	0.14	0.12
Squat jump (cm)		Mean	28	30
		SD	4	4
Counter movement jump without arms (cm)		Mean	30	30
		SD	5	3
Counter movement jump with arms (cm)		Mean	33	34
		SD	5	3
The Yo-Yo intermittent recovery test (m)		Mean	1139	1105
		SD	323	271
The Multi-stage fitness test (m)		Mean	1611	1607
		SD	198	261

U13/U14s

There was a 7 month difference in estimated chronological age between the earlier and later maturers ($p < 0.01$). However, chronological age was not significantly different when the data collection took place. Moreover, earlier maturers covered a significantly longer distance than later maturers in the Multi-stage fitness test ($p < 0.05$). There were no other significant differences demonstrated between earlier and later maturing boys in physical characteristics and performance (table 7.9).

Table 7.9 Physical characteristics of earlier and later maturers from the U13 & U14 squads.

		Earlier	Later
N		12	12
Chronological age (years)	Mean	13.5	13.6
	SD	0.6	0.6
Estimated chronological age at PHV (years)	Mean	13.1**	13.8
	SD	0.2	0.3
Standing height (cm)	Mean	170.2	167.3
	SD	4.9	8.6
Body mass (kg)	Mean	59.6	55.6
	SD	5.8	8.9
Sum of 4 skinfold sites (mm)	Mean	29.7	30.7
	SD	5.3	3.8
Estimated body fat composition (%)	Mean	13.2	13.7
	SD	2.9	2.5

**$p < 0.01$ significantly different to later maturers.

Table 7.9 (continued) Physical characteristics of earlier and later maturers from the U13 & U14 squads.

			Earlier	Later
N			12	12
Sprints (s)				
	5 m	Mean	1.04	1.03
		SD	0.03	0.07
	10 m	Mean	1.77	1.81
		SD	0.06	0.09
	15 m	Mean	2.46	2.52
		SD	0.08	0.15
	20 m	Mean	3.12	3.19
		SD	0.11	0.19
	30 m	Mean	4.41	4.52
		SD	0.16	0.27
Slalom agility test (s)		Mean	4.31	4.29
		SD	0.08	0.14
505 agility test (s)		Mean	2.45	2.48
		SD	0.09	0.09
Squat jump (cm)		Mean	35	35
		SD	5	4
Counter movement jump without arms (cm)		Mean	37	35
		SD	4	4
Counter movement jump with arms (cm)		Mean	42	41
		SD	4	7
The Yo-Yo intermittent recovery test (m)		Mean	1730	1527
		SD	397	453
The Multi-stage fitness test (m)		Mean	2047*	1835
		SD	237	214

*$p < 0.05$ significantly different to later maturers.

U15/U16

There was a 10 month difference in estimated chronological age at PHV between the earlier and later maturing boys ($p < 0.01$), but chronological age was the same at the time of testing. Moreover, earlier maturers demonstrated a significantly heavier body mass, a thicker sum of 4 skinfold sites and a higher estimated body fat composition compared to the later maturers ($p < 0.01$ for all). No other significant differences in physical characteristics or performance between earlier and later maturing boys were demonstrated (table 7.10).

Table 7.10 Physical characteristics of earlier and later maturers from the U15 & U16 squads.

		Earlier	Later
N		13	12
Chronological age (years)	Mean	15.5	15.5
	SD	0.6	0.6
Estimated chronological age at PHV (years)	Mean	13.3**	14.1
	SD	0.3	0.2
Standing height (cm)	Mean	179.0	174.2
	SD	5.5	6.9
Body mass (kg)	Mean	72.0**	64.0
	SD	3.9	7.3
Sum of 4 skinfold sites (mm)	Mean	34.7**	25.5
	SD	7.1	3.9
Estimated body fat composition (%)	Mean	13.9**	9.6
	SD	3.5	2.2

**$p < 0.01$ significantly different to later maturers.

Table 7.10 (continued) Physical characteristics of earlier and later maturers from the U15 & U16 squads.

		Earlier	Later
N		13	12
Sprints (s)			
5 m	Mean	0.99	1.00
	SD	0.04	0.05
10 m	Mean	1.73	1.74
	SD	0.04	0.07
15 m	Mean	2.40	2.40
	SD	0.06	0.08
20 m	Mean	3.02	3.02
	SD	0.06	0.09
30 m	Mean	4.24	4.23
	SD	0.09	0.13
Slalom agility test (s)	Mean	4.10	4.15
	SD	0.11	0.21
505 agility test (s)	Mean	2.29	2.43
	SD	0.35	0.23
Squat jump (cm)	Mean	36	37
	SD	3	5
Counter movement jump without arms (cm)	Mean	38	38
	SD	3	4
Counter movement jump with arms (cm)	Mean	44	47
	SD	3	5
The Yo-Yo intermittent recovery test (m)	Mean	2132	2213
	SD	341	437
The Multi-stage fitness test (m)	Mean	2205	2282
	SD	200	174

U17/U18

There was a 7 month difference in estimated chronological age for the earlier and later maturers ($p < 0.01$), but chronological age at the time of data collection was the same. Sum of 4 skinfold sites was thicker ($p < 0.05$) and estimated body fat composition was higher ($p < 0.01$) for the earlier maturers compared to the later maturers. Moreover, earlier maturers covered a significantly shorter distance than later maturers during the Yo-Yo intermittent recovery test ($p < 0.01$). There were no other significant differences observed between earlier and later maturing boys in physical characteristics and performance (table 7.11).

Table 7.11 Physical characteristics of earlier and later maturers from the U17 & U18 squads.

		Earlier	Later
N		12	12
Chronological age (years)	Mean	17.4	17.4
	SD	0.5	0.6
Estimated chronological age at PHV (years)	Mean	13.6**	14.2
	SD	0.3	0.3
Standing height (cm)	Mean	182.0	179.8
	SD	4.5	6.4
Body mass (kg)	Mean	76.0	73.9
	SD	5.4	6.1
Sum of 4 skinfold sites (mm)	Mean	38.4*	30.3
	SD	9.9	4.3
Estimated body fat composition (%)	Mean	15.0**	11.7
	SD	3.5	2.0

*p < 0.05, **p < 0.01 significantly different to later maturers.

Table 7.11 (continued) Physical characteristics of earlier and later maturers from the U17 & U18 squads.

			Earlier	Later
N			12	12
Sprints (s)				
	5 m	Mean	0.98	0.98
		SD	0.05	0.04
	10 m	Mean	1.69	1.71
		SD	0.07	0.05
	15 m	Mean	2.37	2.37
		SD	0.09	0.07
	20 m	Mean	2.99	2.97
		SD	0.10	0.07
	30 m	Mean	4.17	4.14
		SD	0.13	0.10
Slalom agility test (s)		Mean	3.99	3.96
		SD	0.12	0.11
505 agility test (s)		Mean	2.35	2.30
		SD	0.06	0.08
Squat jump (cm)		Mean	38	39
		SD	4	4
Counter movement jump without arms (cm)		Mean	40	39
		SD	3	3
Counter movement jump with arms (cm)		Mean	46	47
		SD	4	5
The Yo-Yo intermittent recovery test (m)		Mean	2267**	2657
		SD	307	282

**$p < 0.01$ significantly different to later maturers.

7.4 Discussion

This study used stage of genital development (Tanner, 1962), stage of pubic hair development (Tanner, 1962) and estimated chronological age at PHV (Mirwald et al., 2002) to assess biological maturity in 8 to 18 years old elite youth soccer players and to examine the influence of biological maturity on physical characteristics and performance. All methods of biological maturity assessment showed a positive influence on the physical characteristics of elite youth soccer players. The physical characteristics influenced by biological maturity were standing height, body mass, sum of 4 skinfold sites and estimated body fat. The performance on some field tests was also influenced by maturity including the Slalom agility test, counter movement jump without and with arms and the Multi-stage fitness test.

Regardless of the method used to determine maturity in the present study, earlier maturing players were advantaged in terms of physical characteristics which are consistent with the small number of previous studies on the topic (Hulse, 2010, unpublished; Malina et al., 2000; Malina et al., 2004b). Stage of genital development (Tanner, 1962) showed an influence of maturity on standing height and body mass in the U12, U13 and U14 squads. However, stage of pubic hair development (Tanner, 1962) demonstrated an influence of maturity only on standing height in the U12 and U14 squads and on body mass in the U14 squad. In an earlier study, the standing height and body mass of all age groups from the U12-U14 was positively influenced by biological maturity as assessed by stage of pubic hair development (Hulse, 2010, unpublished). Moreover, in the present study estimated chronological age at PHV showed an influence of biological maturity on standing height in the U11 and U12 squads and on body mass in the U9/U10, U11/U12s and U15/U16s. Hence, standing height and body mass were the characteristics which were significantly influenced by biological maturity in wide range of age groups from Premier League Academy player. Moreover, the current study suggests that stage of genital development (Tanner, 1962) is more sensitive to detect differences in standing height and body mass compared to stage of pubic hair development and estimated chronological age at PHV in elite youth soccer players. This is possibly because it is harder to observe a difference in stage of pubic development than stage of genital development. For example, it may not be easy to see a difference in amount of pubic hair between the stages and some players may not gain the amount of pubic hair shown in stage 5 of pubic hair development even when they fully mature. Hence, there may be a less variance in stage of pubic hair development and therefore, less influence of biological maturity was detected when stage of pubic hair development was employed (Malina et al., 2004a). Whether or not height and body mass are advantageous in soccer is open to discussion, but it has been found that club managers tend to choose the taller and heavier players to take the field (Hulse, 2010, unpublished), perhaps believing that those players have a greater physical presence on the pitch. However, such difference in body size disappeared when the players reached the U17/U18 squad and full or almost full maturational status (Hulse, 2010, unpublished). Therefore, the football clubs may need to control maturational status to minimise the influence of maturity on body size whilst there is a variation in maturational status.

The sum of 4 skinfold sites and estimated body fat were higher in the earlier maturing players in the U11/U12s, U15/U16s and U17/U18s (estimated chronological age at PHV). These findings are consistent with an earlier study on 11-12 (N = 87) and 13-14 (N = 72) year old non-elite youth soccer players (Figueiredo et al., 2009) and with previous studies on sedentary boys (Malina et al., 1999; Van Lenthe et al., 1996). The reasons for this finding are unknown, but the earlier maturing boys in the present study were identified as earlier maturers by the estimated chronological age at PHV. Thus, many of these boys had not actually gone through puberty at the time of testing and may have been accumulating additional fat in anticipation of major changes occurring around the time of the actual PHV.

Maturity did not significantly impact on sprint performance in the present study over 5, 10, 15, 20 and 30 m regardless of the method used to determine maturity. However, in the U13 squad there was a tendency for the players in stage 5 of genital development to be faster than the players in stage 3 over 30 m ($p = 0.088$) and for the players in stage 5 of pubic hair development to be faster than the players in stage 3 over 5 m ($p = 0.054$). It has been previously reported that stage of pubic hair development showed a significant influence on 30 m sprint performance in 13-15 years (N = 69) old Portuguese elite soccer players (Malina et al., 2004b). Moreover, U11-U13 players in a higher stage of pubic hair development were faster over 10 and 20 m than players in lower stages in the one previously unpublished study on the U11, U12 and U13 English Premier League Academy players (N = 39-47, Hulse, 2010, unpublished). Although the present study had a large number of participants (162 players), when these players were subdivided into age group squads, some of the Ns became quite small and this may have affected the achievement of statistical significant. Thus, on balance, the findings relating to the impact of maturity on sprint performance in the present study are consistent with the earlier two studies on the topic.

There was an influence of biological maturity on Slalom agility test performance in the U12 squad when stage of pubic hair development was used to assess maturity and the players in stage 3 were significantly faster than the players in stage 2. However, no other significant influence of biological maturity was found in Slalom agility test performance regardless of method of biological maturity assessment. In addition, the 505 agility test performance was not influenced by biological maturity regardless of the method of biological maturity assessment used. Similarly, a previous study with the U9-U19 English Premier League Academy players (N = 30+ in each of U9-U16 age groups) showed no influence of biological maturity in Slalom agility test performance in all age groups when each age group was analysed separately based on stage of pubic hair development. These findings may suggest that agility is less influenced by maturity than some other performance variables in elite youth soccer players.

The performance of the counter movement jump with the arms was higher for the U13 players in stage 4 of genital development than for players in stage 3. There were no other significant influences of biological maturity on the three standing vertical jumps regardless of method employed to assess biological maturity in the elite youth soccer players. However, there was a tendency for the U13 squad to be influenced by stage of genital development in performance during the counter movement jump without arms ($p = 0.115$). Moreover, there was a tendency for performance during counter movement jump without arms in the U13 squad ($P = 0.118$) and performance during counter movement jump with arms in the U12 ($P = 0.073$) and U13 ($P = 0.113$) to be influenced by stage of pubic hair development. In addition, the U12 players in stage 4 of pubic hair development tended to perform better in counter movement jump with arms compared to the players in stage 2 ($P = 0.063$). These findings are consistent with the earlier unpublished study where maturity (pubic hair) impacted positively on standing vertical jump in the U12, U13, U15 and U16 squads (Hulse, 2010, unpublished) and in 13-15 years old elite soccer players from Portugal (Malina et al., 2004b). Therefore, the current study seems to be in line with previous studies even though the statistically significant differences were not obtained on many occasions.

Biological maturity positively influenced performance during the Multi-stage fitness test in the U13 squad when both stage of genital and pubic hair development (Tanner, 1962) were used to determine maturation and in the U13/U14s when estimated chronological age at PHV (Mirwald et al., 2002) was used. Similarly, more mature elite Portuguese soccer players (13-15 years old) performed better during the Yo-Yo intermittent endurance test (level 1), but maturity did not impact on the Multi-stage fitness test performance in the U9-U19 English Premier League Academy players (Hulse, 2010, unpublished). The largest improvement in endurance ability has been suggested to occur on or just after PHV (Philippaerts et al., 2006; Yague and De La Fuente, 1998). Thus, the strong evidence from the present study, using 3 different maturity methods, that maturity does impact on the Multi-stage fitness test performance may be because of the larger variation in maturity and Multi-stage fitness test performance in this age group. The lack of any relationships between maturity and the Yo-Yo intermittent recovery test (level 1) performance in the present study in boys under 16 years of age may be due to the additional co-ordination requirements of the Yo-Yo intermittent recovery test (level 1) which may be negatively influenced by changes in leg and arm length around the time of PHV (Robertson and Halverson, 1988). The poorer performance of 17/18 year old earlier maturing boys on the Yo-Yo intermittent recovery test (level 1) may be because biological maturity assessed by estimated chronological age at PHV has no more influence as all players must have obtained PHV by the time they are 17 years old or because these more mature boys are carrying a greater fat mass. The findings from the current and previous studies showed that biological maturity influences physical performance including sprint, agility, standing vertical jumps and endurance in elite youth soccer players especially in the U11-U16 age groups. Therefore, the clubs are recommended to consider grouping players by maturity in these age groups or at least to take into account that later maturing boys will be disadvantaged to minimise the influence of biological maturity on selection issues and to optimise development.

When distribution of stage of pubic hair development (Tanner, 1962) from the current study was compared to a previous study (Hulse, 2010, unpublished), the players from the current study were possibly more sexually mature. Nearly one-fifth (18%) of the U13 players from the current study belonged to stage 5 of pubic hair development (Tanner, 1962) opposed to 0% in the previous study and 33% of the players in the U14 squad from the current study identified themselves in stage 5 of pubic hair development (Tanner, 1962) opposed to 17% in the previous study. Therefore, distribution of sexual maturity seems to be shifted towards more mature stages in the current study compared to the past finding (Hulse, 2010, unpublished) especially in the U13 and U14 squads.

The participants recruited in the current study did not include any late maturers. It has been previously suggested that the average chronological age for gaining PHV is 14.0 years and boys who lie within a year on each side are categorised as average maturers and, boys who fall earlier or later than this range are classified as early and late maturers (Sherar et al., 2005). All of the participants who participated in this study were categorised into early or average maturers in every squad, which might suggest that the selection policy for this club excludes late maturing boys.

There were a small number of limitations to the present study including the relatively small participant N for some age groups when maturity was assessed by stage of genital and pubic hair development and the fact that all players were recruited from only one club. Also the need to combine age groups (e.g., U9/U10s, U11/U12s) for the estimated chronological age at PHV may have affected the achievement of statistical significance due to, for example, earlier maturing 9 year olds having a poorer performance than later maturing 10 year olds resulting in overlapping performance results in the combined earlier and later maturing groups. Nevertheless, the present study is novel in that: only one study in 13-15 year olds has been previously published on the maturity and physical characteristics and performance of elite youth soccer players; it is the first study to use more than one test to determine maturity and; the effect of maturity has been examined on a wider range of tests (e.g., Slalom and 505 agility test and the Multi-stage fitness test) than has been previously published.

In conclusion, when stage of genital development, stage of pubic hair development and estimated chronological age at PHV were employed to assess biological maturity, both the physical characteristics and field test performance of 8 to 18 years old Premier League Academy players were influenced by biological maturity. Furthermore, there were no late maturers amongst the 162 boys taking part in the study. Therefore, maturity does impact on physical characteristics and field test performances in elite youth academy players. The clubs are recommended to consider grouping players by maturity in these age groups or at least to take into account that later maturing boys will be disadvantaged to minimise the influence of biological maturity on selection issues and to optimise development.

Chapter 8
Biological maturity and high intensity match running performance of elite youth soccer players

8.1 Introduction

In adolescent boys, biological maturity has been shown to influence standing height and body mass (Malina, 1988; Yague and De La Fuente, 1998). In youth soccer, older and more mature players have been reported to gain advantages in the player selection process (Carling et al., 2009) and a limited number of studies have shown that elite youth soccer players have an advanced biological maturity status (Baxter-Jones and Helms, 1996; Malina et al., 2004b). Different methods to assess biological maturity have been used. In youth soccer players, secondary sexual maturation (Figueiredo et al., 2009; Malina et al., 2004b), skeletal age (Carling et al., 2009; le Gall et al., 2010; Malina et al., 2000) and chronological age at peak height velocity (PHV) (Philippaerts et al., 2006) have been popularly employed. Furthermore, measurements including standing height, sitting height, body mass and chronological age collected from a single session have been used to estimate chronological age at PHV and this method has been validated for participants with a chronological age range of 7 to 18 years (Mirwald et al., 2002). However, no study has used the methods of examining secondary sexual maturation and the estimated chronological age at PHV in the same study (other than Chapter 7 for physical characteristics and physical performance).

Previous research has examined the influence of biological maturity on the physical characteristics of youth soccer players. Advanced biological maturity has been shown to positively influence standing height, body mass, skinfold thickness and estimated body fat composition in 8 to 18 years old soccer players from Portuguese and English clubs (Chapter 7; Figueiredo et al., 2009; Hulse, 2010, unpublished; Malina et al., 2000; Malina et al., 2004b). Moreover, biological maturity has been shown to influence the physical performance of youth soccer players. It was reported that 10 to 15 years old elite players from Portuguese and English clubs with a higher stage of pubic hair development (Tanner, 1962) performed significantly better than counterparts with lower stage of pubic hair development in a 10 to 30 m sprint test (Hulse, 2010, unpublished; Malina et al., 2004b) and, the U12 players from the English Premier League Academy with advanced maturity performed better in an agility test compared to the counterparts with lower maturational status (Chapter 7). For standing vertical jumps, a higher jump height was shown by 11 to 16 year olds with advanced maturity in elite players from Portuguese and English clubs compared to the counterparts with lower maturity status (Hulse, 2010, unpublished; Malina et al., 2004b). In addition, youth soccer players from English and Portuguese clubs (11 to 15 years old players) with advanced biological maturity performed better in endurance tests (Multi-stage fitness test; Yo-Yo intermittent endurance test (level 1); Yo-Yo intermittent recovery test (level 1)) compared to counterparts with lower maturity status (Chapter 7; Figueiredo et al., 2009; Malina et al., 2004b). Therefore, the influence of biological maturity on several aspects of physical characteristics and physical performance has been examined, but no previous research has examined on the effect of biological maturity on actual match play in elite youth soccer players.

The Long-Term Athlete Development Model (Balyi and Hamilton, 2004) was established to support the production of elite sport performers and the English FA has produced a Long-Term 'Player' Development Model (Simmons, 2005) based on the model. These models separated the period from prepubescent to postpubescent into several stages and mainly recommend key aspects to focus upon in training (e.g. skills, coordination for basic movements, endurance etc), how to deliver the training and the appropriate ratio of training and competition. However, the model provides little information concerning the impact of maturation on performance and selection and information concerning the impact of maturation on match play would add to the very limited scientific evidence upon which the model is based (Ford et al., 2011).

Hence, aim of this study was to examine the influence of biological maturity on the high intensity match running performance of elite youth soccer players from the U9 to U16 squads using three methods to assess biological maturity. The findings may help coaches and staff in the process of talent identification and may provide scientific evidence to underpin the Long-Term Athlete Development Model and the Long-Term Player Development Model. Based on previous literature, it was hypothesised that advanced biological maturity will positively influence the high intensity match running performance of elite youth soccer players.

8.2 Methods

8.2.1 Participants

The participants were 102 Premier League Academy players from a club in the East Midlands and their chronological age ranged from 8.4 to 16.2 years. Each age group formed a squad from the U9 to U16. The U9-U14 squads had 3 training sessions a week and the U15 and U16 squads had 4 training sessions a week. All squads had an average of one match per week during the season. Players were provided with a written and verbal explanation of the study including all tests and measurements to be taken. Each player signed an informed consent form and completed a health screen questionnaire prior to participation in the study. Players' parents, guardians or care-givers signed the consent form prior to the start of the study. Participants were withdrawn from a particular test if they did not have a satisfactory health status. The study was approved by Loughborough University Ethical Committee.

8.2.2 Assessment of biological maturity

Biological maturity was assessed as described in Chapter 3. Briefly, stage of genital development (Tanner, 1962) and stage of pubic hair development (Tanner, 1962) were self-assessed by the players using photographs of secondary sexual development. Estimated chronological age at PHV was determined using chronological age, sitting height, standing height and body mass (Mirwald et al., 2002). Stage of genital development and stage of pubic hair development (Tanner, 1962) were employed to assess the biological maturity of the U12 and U13 squads and they were combined to form one group in statistical analysis. The U14 squad was not included in the analysis because these older boys changed the chronological age of each maturity group which would have made any comparisons on the basis of maturity invalid. Estimated chronological age at PHV (Mirwald et al., 2002) was used to assess biological maturity of the U9-U16 squads. The players from each squad (e.g., U10s) were separated into two groups based on their estimated chronological age at PHV (earlier maturers and later maturers). Then to ensure a large enough number of participants in each group for statistical analyses, the players were grouped as follows: U9/U10s, U11/U12s, U13/U14s and U15/U16s.

8.2.3 Match analysis

The match analysis procedures used were as described in Chapter 3. The mean of the performance data for two or more matches was accepted to represent the match performance for that player (mean ± SD = 4 ± 2 matches: range = 2-13 matches). Only the match running performance variables related to high intensity activities (total distance covered and distance covered by moderate and high speed running per match and per hour of a match and, percentage of time spent in moderate and high speed running) were included in the analysis as it has been reported that high intensity activities are more important in distinguishing the standard of soccer players (Bangsbo et al., 1991; Mohr et al., 2003). It has been previously reported that for high speed running (> 19.8 $km \cdot h^{-1}$), the coefficient of variation was 16-20% in elite senior soccer players from 7281 matches with 485 players (median = 10 matches per player: range = 2-57 matches per player) (Gregson et al., 2010). Hence as many matches as possible should be analysed per player to reduce the effects of match-to-match variation. However, the U9-U14 squads included in the current study only played 24 inter-academy matches during a season and they were on the same day and at the same time. Therefore, for most squads, only a maximum of 4 matches per squad was available to analyse in a season (except for the U15 and U16 squads who played on Saturdays) as the data collection had to be rotated around the squads.

8.2.4 Statistical analyses

Descriptive statistics were calculated for the players in each category of maturational status. Statistical analysis was conducted when there were at least five participants. An independent sample t-test was used to compare the players in stage 3 and 4 of genital development, players in stage 3 and 4 of pubic hair development and, earlier and later maturers (estimated chronological age at PHV). Results are presented as mean ± standard deviation (SD) and PASW 18.0 was used for all the statistical analyses. In tables, stage of genital development and stage of pubic hair development are expressed as G and PH, respectively (e.g., stage 3 of genital development = G3). Goalkeepers were excluded from all statistical analysis and data presented. Level of statistical significance was set at $p < 0.05$.

8.3 Results

8.3.1 Stage of genital development and match performance of the U12 and U13 squads

Due to differences in chronological age, stage 2 of genital development was not included in the statistical analysis. There were no significant differences in chronological age and mean playing time between the players in stage 3 and 4. However, the players in stage 4 covered a significantly longer distance by high speed running during a match compared to the players in stage 3 ($p < 0.05$). No other significant differences were found between the players in stage 3 and 4 (table 8.1). However, there was a tendency for the players from stage 4 to cover a longer distance by high speed running per hour of a match compared to the players in stage 3 ($p = 0.065$).

Table 8.1 Stage of genital development and high intensity match running performance of the U12 and U13 players.

			1	2	3	4	5
N			2	5	11	8	1
Chronological age (years)		Mean	12.2	12.1	12.7	12.8	13.5
		SD	0.2	0.6	0.5	0.6	
Mean playing time (min)		Mean	67.8	57.9	56.3	61.7	69.1
		SD	4.6	9.9	9.3	11.2	
Distance covered ($m \cdot match^{-1}$)	*Total*	Mean	6387	5842	5660	6231	7039
		SD	145	701	798	1274	
	Moderate speed running	Mean	1003	905	899	996	822
		SD	18	131	196	414	
	High speed running	Mean	502	535	445	609*	450
		SD	77	244	116	163	

*$p < 0.05$ significantly different to G3.

Table 8.1 (continued) Stage of genital development and high intensity match running performance of the U12 and U13 players.

			1	2	3	4	5
N			2	5	11	8	1
Distance covered (m·hour^{-1})	*Total*	Mean	5673	6104	6059	6059	6108
		SD	509	436	329	485	
	Moderate speed running	Mean	891	946	960	955	840
		SD	75	107	181	300	
	High speed running	Mean	448	585	478	602	474
		SD	98	328	128	147	
Percentage of time (%)	*Moderate speed running*	Mean	6.8	7.1	7.2	7.1	6.3
		SD	0.6	0.8	1.4	2.2	
	High speed running	Mean	2.5	3.2	2.7	3.2	2.6
		SD	0.5	1.7	0.7	0.8	

8.3.2 Stage of pubic hair development and match performance of the U12 and U13 squads

Chronological age was significantly older for players in stage 4 compared to players in stage 2 ($p < 0.05$). Therefore, stage 2 was not included in the statistical analysis. No significant differences in mean playing time, total distance covered during a match and high intensity match running performances were found between the U12 and U13 players in stage 3 and 4 of pubic hair development (table 8.2).

Table 8.2 Stage of pubic hair development and high intensity match running performance of the U12 and U13 players.

			1	2	3	4	5
N			1	6	11	8	1
Chronological age (years)		Mean	12.4	12.1	12.7	12.9	13.5
		SD		0.6	0.5	0.6	
Mean playing time (min)		Mean	71.0	60.0	55.9	61.4	69.1
		SD		7.6	10.0	11.1	
Distance covered ($m \cdot match^{-1}$)	*Total*	Mean	6285	6024	5549	6328	7039
		SD		642	799	1208	
	Moderate speed running	Mean	991	931	873	1079	1093
		SD		156	169	357	
	High speed running	Mean	448	554	491	571	680
		SD		187	112	193	

Table 8.2 (continued) Stage of pubic hair development and high intensity match running performance of the U12 and U13 players.

			1	2	3	4	5
	N		1	6	11	8	1
Distance covered (m·hour^{-1})	*Total*	Mean	5313	6040	5989	6194	6108
		SD		250	359	486	
	Moderate speed running	Mean	991	931	873	1079	1093
		SD		156	168	357	
	High speed running	Mean	448	554	491	571	680
		SD		187	112	193	
Percentage of time (%)	*Moderate speed running*	Mean	6.4	7.1	6.8	7.8	6.9
		SD		1.0	1.2	2.0	
	High speed running	Mean	2.2	3.2	2.9	3.0	3.2
		SD		1.3	0.8	0.9	

8.3.3 Estimated chronological age at PHV and match performance of the U9-U16 squads

U9/U10

There was a 6 month difference in estimated chronological age for the earlier and later maturers ($p < 0.01$), but chronological age at the time of data collection was the same. Compared to later maturers, earlier maturers demonstrated a significantly longer mean playing time for a match ($p < 0.05$) and covered a significantly longer distance in a match ($p < 0.05$). No other significant differences in high intensity match performance were found between earlier and later maturers in the U9/U10s (table 8.3).

Table 8.3 High intensity match running performance of earlier and later maturers from the U9 and U10 squads according to estimated chronological age at PHV.

U9 & U10 squads			Earlier	Later
N			14	15
Chronological age (years)		Mean	9.3	9.3
		SD	0.5	0.5
Estimated chronological age at PHV (years)		Mean	12.7**	13.2
		SD	0.4	0.3
Mean playing time (min)		Mean	56.3*	52.3
		SD	4.9	4.5
Distance covered (m·match^{-1})	*Total*	Mean	4499*	4125
		SD	527	387
	Moderate speed running	Mean	493	461
		SD	128	111
	High speed running	Mean	175	173
		SD	70	44
Distance covered (m·hour^{-1})	*Total*	Mean	4793	4747
		SD	362	369
	Moderate speed running	Mean	528	535
		SD	139	147
	High speed running	Mean	188	200
		SD	76	53
Percentage of time (%)	*Moderate speed running*	Mean	4.4	4.4
		SD	1.1	1.2
	High speed running	Mean	1.2	1.3
		SD	0.5	0.3

*p < 0.05, **p < 0.01 significantly different to later maturers.

U11/U12

There was a 6 month difference in estimated chronological age at PHV between the earlier and later maturing boys ($p < 0.01$). However, chronological age was the same when the measurements were taken and no differences in high intensity match running performances were observed between earlier and later maturing boys in the U11/U12s (table 8.4).

Table 8.4 High intensity match running performance of earlier and later maturers from the U11 and U12 squads according to estimated chronological age at PHV.

U11 & U12 squads			Earlier	Later
N			16	17
Chronological age (years)		Mean	11.6	11.6
		SD	0.5	0.5
Estimated chronological age at PHV (years)		Mean	13.3**	13.8
		SD	0.3	0.2
Mean playing time (min)		Mean	59.1	59.9
		SD	9.8	9.1
Distance covered ($m \cdot match^{-1}$)	*Total*	Mean	5620	5744
		SD	906	774
	Moderate speed running	Mean	875	905
		SD	182	148
	High speed running	Mean	501	515
		SD	155	99
Distance covered ($m \cdot hour^{-1}$)	*Total*	Mean	5730	5774
		SD	459	339
	Moderate speed running	Mean	898	915
		SD	180	141
	High speed running	Mean	527	525
		SD	202	112
Percentage of time (%)	*Moderate speed running*	Mean	6.9	7.1
		SD	1.4	1.1
	High speed running	Mean	3.0	3.1
		SD	1.0	0.7

*$p < 0.05$, **$p < 0.01$ significantly different to later maturers.

U13/U14

There was an 11 month difference in estimated chronological age between the earlier and later maturers ($p < 0.01$). However, chronological age was not significantly different when the data collection took place. Moreover, earlier maturers covered a significantly longer distance per hour of a match by high speed running compared to later maturers ($p < 0.05$). Furthermore, earlier maturers spent longer percentage of time in high speed running during a match compared to later maturers ($p < 0.05$). There were no other significant differences in high intensity match running performance between earlier and later maturers in the U13/U14s (table 8.5).

Table 8.5 High intensity match running performance of earlier and later maturers from the U13 and U14 squads according to estimated chronological age at PHV.

U13 & U14 squads			Earlier	Later
N			10	10
Chronological age (years)		Mean	13.7	13.4
		SD	0.5	0.6
Estimated chronological age at PHV (years)		Mean	13.1**	14.0
		SD	0.3	0.2
Mean playing time (min)		Mean	57.2	56.5
		SD	8.6	8.0
Distance covered ($m \cdot match^{-1}$)	*Total*	Mean	5946	5927
		SD	1053	927
	Moderate speed running	Mean	909	946
		SD	342	236
	High speed running	Mean	612	483
		SD	150	167
Distance covered ($m \cdot hour^{-1}$)	*Total*	Mean	6235	6291
		SD	440	291
	Moderate speed running	Mean	944	996
		SD	250	129
	High speed running	Mean	646*	507
		SD	134	125
Percentage of time (%)	*Moderate speed running*	Mean	6.8	7.1
		SD	1.9	0.9
	High speed running	Mean	3.4*	2.7
		SD	0.7	0.6

*p < 0.05, **p < 0.01 significantly different to later maturers.

U15/U16

There was a 8 month difference in estimated chronological age at PHV between the earlier and later maturing boys ($p < 0.01$), but chronological age was the same at the time of testing. However, no significant differences in high intensity match running performances were demonstrated between earlier and later maturers in the U15/U16s (table 8.6).

Table 8.6 High intensity match running performance of earlier and later maturers from the U15 and U16 squads according to estimated chronological age at PHV.

U15 & U16 squads			Earlier	Later
N			10	10
Chronological age (years)		Mean	15.4	15.5
		SD	0.5	0.7
Estimated chronological age at PHV (years)		Mean	13.3**	14.0
		SD	0.3	0.3
Mean playing time (min)		Mean	69.0	74.5
		SD	13.9	7.4
Distance covered ($m \cdot match^{-1}$)	*Total*	Mean	7536	8354
		SD	1479	908
	Moderate speed running	Mean	1126	1277
		SD	2634	253
	High speed running	Mean	575	695
		SD	175	211
Distance covered ($m \cdot hour^{-1}$)	*Total*	Mean	6568	6738
		SD	317	420
	Moderate speed running	Mean	986	1033
		SD	159	183
	High speed running	Mean	501	561
		SD	123	153
Percentage of time (%)	*Moderate speed running*	Mean	6.6	6.9
		SD	1.1	1.2
	High speed running	Mean	2.5	2.8
		SD	0.6	0.7

**$p < 0.01$ significantly different to later maturers.

8.4 Discussion

This study was the first to examine the influence of biological maturity on high intensity match running performance in elite youth soccer players using three different methods of biological maturity assessment. When stage of genital development was employed to examine biological maturity, the U12 and U13 players from stage 4 covered a significantly longer distance by high speed running per match compared to the players in stage 3. When estimated chronological age at PHV (Mirwald et al., 2002) was employed to assess biological maturity, earlier maturers were selected by coaches for a longer playing time and covered a significantly longer total distance during a match compared to later maturers in the U9/U10s. Moreover, earlier maturers (estimated chronological age at PHV (Mirwald et al., 2002)) covered a significantly longer distance per hour and spent a significantly higher percentage of time in high speed running during a match compared to later maturers in the U13/U14s. Such differences in high intensity match running performances were not observed in the U12 and U13 squads when stage of pubic hair development was employed and in the U11/U12s and U15/U16s when estimated chronological age at PHV was used to assess biological maturity.

When biological maturity was examined with stage of genital development (Tanner, 1962), the U12 and U13 squads showed that the players in stage 4 covered a longer distance by high speed running during a match ($p < 0.05$) compared to the players in stage 3. Moreover, when the distance covered by high speed running was standardised into metres per hour, there was a tendency for the players from stage 4 to cover a longer distance than players in stage 3 by high speed running ($p = 0.065$). These differences suggest that biological maturity positively influences high speed running performance of elite youth soccer players when stage of genital development was employed to assess biological maturity. Hence, coaches may wish to consider separating the players according to biological maturity rather than, or in addition to, separating by age group to optimise player development and to make the selection process more accurate and, from the players' point of view, fairer.

When stage of pubic hair development was employed to examine biological maturity, the U12 and U13 players who were categorised in stage 3 and 4 did not show any significant differences in any of the high intensity match running performance variables even though the players in stage 4 showed a higher value in all variables compared to the players in stage 3. This is an interesting finding as stage of genital development teased out a positive influence of biological maturity in high speed running performances during a match. This may suggest that stage of genital development is more sensitive to detect differences in high intensity match running performance than stage of pubic hair development in the U12 and U13 elite youth soccer players.

When estimated chronological age at PHV (Mirwald et al., 2002) was employed to assess biological maturity, there were no significant differences between earlier and later maturers in all high intensity match running performance variables when they were standardised into per hour of a match in the U9/U10s. However, earlier maturers were gaining a significantly longer playing time and this resulted in early maturers covering ~10% (~400 m, $p < 0.05$) longer total distance during a match compared to late maturers. These earlier maturers are selected by coaches to spend more time on the pitch and gain all the developmental advantages associated with this greater playing time.

In the U13/U14s, earlier and later maturers were given the same amount of playing time and, covered a similar distance in total during a match and by high and moderate speed running when estimated chronological age at PHV was employed to assess biological maturity. However, earlier maturers covered a significantly longer distance than later maturers by high speed running per hour of a match. Moreover, earlier maturers spent a higher percentage of time performing high speed running compared to later maturers. Therefore, biological maturity positively influences distance covered by high speed running per hour of a match and percentage of time spent in high speed running in the U13 and U14 elite youth soccer players.

Interestingly, no significant differences in high intensity match running performance variables were found between earlier and later maturers in the U11/U12s and the U15/U16s when estimated chronological age at PHV (Mirwald et al., 2002) was employed to examine biological maturity. The U9/U10s showed a significant difference in total distance covered during a match. However, this was due to a longer playing time given to earlier maturers compared to later maturers and the difference no longer existed when it was standardised into metres per hour. On the other hand, differences in high intensity match running performance were found between earlier and later maturers in the U13/U14s when estimated chronological age at PHV (Mirwald et al., 2002) was employed to examine biological maturity and, the U12 and U13 squads revealed that players in stage 4 of genital development covered a significantly longer distance by high speed running in a match compared to the players in stage 3. These findings may suggest that an influence of biological maturity on high intensity match running performance only exists when the elite youth soccer players are going through puberty. Therefore, coaches who work with elite youth soccer players need to take account of the influence of biological maturity on high speed running performances during a match when the players go through puberty (Hulse, 2010, unpublished) and to take care to give all younger players a similar playing time on the pitch.

The match running performances observed in the current study were in line with the previous studies (Chapter 5 from this thesis; Castagna et al., 2003). All of the age groups showed a similar high intensity match running performance compared to the results reported in Chapter 5 of this thesis and this was regardless of the methods employed to assess biological maturity. A previous study showed that total distance covered by the U12 Italian soccer players in a 60 minute match was 6175 m which is similar to the total distance covered in an hour by the U12 and U13 squads even when they were separated into different maturity status by stage of genital and pubic hair development (Tanner, 1962) and by earlier and later maturers from the U11/U12s when they were categorised into different maturity status by estimated chronological age at PHV (Mirwald et al., 2002). For the future research, it will be interesting to examine an influence of biological maturity on elite youth soccer players when the players are separated into different playing positions as it has been argued that the playing position influences match running performance during a match (Bradley et al., 2009; Di Salvo et al., 2007; Di Salvo et al., 2009; Rampinini et al., 2007b).

In the current study biological maturity, particularly as assessed by stage of genital development, has been shown to influence the high intensity match running performance of elite youth soccer players. However, influence of biological maturity on high intensity match running performance in different playing positions was not examined due to a lack of participants. A previous study employed stage of pubic hair development (Tanner, 1962) to examine the biological maturity of 13-15 years old elite soccer players and showed that the majority of defenders and strikers were at stage 4 and 5 of pubic hair development and, midfielders were spread across stage 1 to stage 5 of pubic hair development (Malina et al., 2004b). As maturational status varies by playing position and the current study showed that biological maturity influences high intensity match running performance in elite youth soccer players, in future studies the influence of biological maturity needs to be examined by playing position. Such information would again assist coaches and staff with the grouping of players to optimise player development and selection procedures.

In the current study, the influence of biological maturity on high intensity match running performance was different when stage of genital development (Tanner, 1962), stage of pubic hair development (Tanner, 1962) and estimated chronological age at PHV (Mirwald et al., 2002) were employed in elite youth soccer players. When similar age groups were examined (U12 and U13 squads and U13/U14s), estimated chronological age at PHV (Mirwald et al., 2002) showed a more frequent influence of biological maturity on high intensity match running performance compared to stage of genital development (Tanner, 1962) and stage of pubic hair development (Tanner, 1962). Therefore, estimated chronological age at PHV (Mirwald et al., 2002) is possibly the most sensitive method out of these three methods to examine the influence of biological maturity on high intensity match running performance in pubescent elite youth soccer players or at minimum because of ease of measurements it allows more boys to be included in groups for comparison leading to a higher chance of statistically significant difference being observed.

In conclusion, biological maturity significantly influenced high intensity match running performance in the English Premier League Academy players when stage of genital development and estimated chronological age at PHV were employed to assess biological maturity. When stage of genital development was employed, distance covered by high speed running during a match was positively influenced by maturity in the U12 and U13 squads. When estimated chronological age at PHV (Mirwald et al., 2002) was employed to assess biological maturity, earlier maturers covered a significantly longer total distance in a match due to gaining a significantly longer playing time compared to the later maturers in the U9/U10s. Moreover, earlier maturers from the U13/U14s covered a significantly longer distance by high speed running per hour of a match compared to later maturers whilst covering a similar total distance during a similar given playing time. Furthermore, the percentage of time spent in high speed running was significantly higher for earlier maturers than later maturers in the U13/U14s. The practical implications of these findings for coaches and those involved in talent identification and development are that younger boys must be given a similar pitch time during match play and that players need to be grouped based on their maturational status to minimise the differences in high intensity match running performances caused by a variation in biological maturity and to avoid selection errors.

Chapter 9

General discussion

The participants in the studies reported in this thesis were 183 English Premier League Academy players from the U9 to U18 squads. In Chapters 4, 5, 6, 7 and 8, a large number of measurements were taken (4 anthropometric measurements, 12 physical performance tests, 3 different methods for determining biological maturity and match running performances). To the author's knowledge, this is the first study to examine physical characteristics, field test performance, match performance and maturity on such a large group of elite youth soccer players. The descriptions of physical characteristics and field test performance (Chapter 4) and match running performance (Chapter 5) were included in the earlier chapters of the thesis. In the later chapters, the relationship between physical characteristics and high intensity match running performance and between physical performance and high intensity match running performance (Chapter 6) were established as well as the influence of biological maturity on physical characteristics, physical performance (Chapter 7) and high intensity match running performance (Chapter 8). Some of these findings are novel and contribute to furthering understanding of the development of the physical characteristics, physical performance and match running performance of elite youth soccer players.

All the physical performance and match performance data from this thesis (Chapter 4, 5, 6, 7 and 8) were collected during field-based testing while the players were wearing soccer related clothing and footwear and all data collection was conducted on grass or on an artificial grass surface. Therefore, the environment was the same or very close to the real soccer match situation and the validity and reliability of the field tests has been previously examined (Hulse et al, 2012)

The peak velocity of development in most of the physical characteristics, in the field test performances (Chapter 4) and in match running performance (Chapter 5) occurred between the U10-U14 age group squads and in addition there was a large variation in performance within the U12 and U13 age groups in particular. For example, the standard deviation of the U12 and U13 squads distance covered per hour at high speeds was 229 and 153 $m \cdot hour^{-1}$, respectively in comparison with 56-144 $m \cdot hour^{-1}$ for the other squads. In Chapters 7 and 8, it was shown that maturity impacted upon physical characteristics, field test performance and match performance. Moreover, it was shown that there were no late maturing boys within the group. Thus, the greatest rate of change in the 10-14 year old age groups may have been due to the rapidly approaching PHV for these boys, which was earlier than the national average for boys of 14 years of age and the great variation within the U12/U13 groups may reflect the very differing maturity status of boys within these groups. In addition, as suggested in earlier chapters, this period between the age 10 and 14 years is one of rapidly improving co-ordination which may also impact upon the enhanced field test and match performance of the boys (Whitall, 2003).

With the hind-sight of the knowledge relating to the maturity status of the boys described in Chapter 7, the large number of relationships demonstrated between field test performance and high intensity match running performances in the U11-U13 group compared to the U9-U10 and U14-U16 age groups may be explained by the variation in maturity status of the boys in these age groups leading to a wide range of field test performance and a wide range of match performance results. This suggestion is supported by the fact that the U9-U10 squads and U14-U16 squads had less variation in physical characteristics, field test performance and high intensity match running performances resulting in a relationship only between sprint test performance and moderate speed running performance during a match in the U9-U10 squads and no relationships in the U14-U16 group (Chapter 6).

Physical characteristics, field test performances (Chapter 4) and match running performance observed using GPS (Chapter 5) were all influenced by biological maturity as determined by 3 methods which were stage of genital development (Tanner, 1962), stage of pubic hair development (Tanner, 1962) and estimated chronological age at PHV (Mirwald et al., 2002) (Chapter 7 and 8). For these elite youth soccer players, the effect of maturity on standing height and body mass was best identified by stage of genital development, whereas the effect of maturity on field test performance (sprint, agility, counter movement jumps, the Multi-stage fitness test) and on match running performance was best identified using the pubic hair stage methods. When using the estimated chronological age at PHV as the method for determining maturity, maturity was shown to impact upon standing height, body mass, sum of 4 skinfolds and estimated body fat composition, the counter movement jump without arms, the Yo-Yo intermittent recovery test (level 1) and the Multi-stage fitness test (Chapter 7). Therefore, the Tanner stages method and estimated chronological age at PHV method have been shown to be valuable and to give similar results in demonstrating the influence of biological maturity on the physical characteristics and physical performance of elite youth soccer players. Thus, coaches and practitioners can confidently use the estimated chronological age at PHV in the field setting to determine the maturational stage of their players. The method can be used with a wide age range of players and only requires a small number of non-invasive measurements.

Throughout this thesis, sprint tests over 5, 10, 15, 20 and 30 m, 2 agility tests, 3 standing vertical jumps and 2 endurance tests has been used to assess physical performance of elite youth soccer players (Chapter 4, 6 and 7). Each test showed different relationships with match running performance and influence of biological maturity depending on age groups. For the U9 and U10 squad, sprint test over 5 and 20 m may be recommended based on the relationship shown with the high intensity match running performance (Chapter 6). For the U11-U16 squads, sprint tests over 5, 10, 15, 20 and 30 m especially 30 m sprint test would be advisable as 30 m sprint performance explained a variance in high speed running performance during a match (Chapter 6) and it tended to be influenced by biological maturity (genital development) in the U13 squad (Chapter 7). However, the U17 and U18 squads showed no such relationships (Chapter 6) and no influence of biological maturity on sprint performance (Chapter 7) even though the sprint ability was shown to be an important physical performance in the U17 English Premier League Academy players. Slalom and 505 agility tests showed no relationships with match running performance (Chapter 6) and no influence of biological maturity in all age groups except the U12 players as the U12 players in a higher stage of pubic hair development showed a faster Slalom agility test performance compared to the players in lower stage (Chapter 7). Hence, even though importance of agility in elite youth players for subsequent progression to professional football has been reported (Hulse, 2010, unpublished; Reilly et al., 2000), there were no relationships between agility and match performance in the present study. Standing vertical jumps may not be recommended in the U9 and U10 squads due to undeveloped jump technique due to a lack of coordination (Roberton and Halverson, 1988) based on the result from Chapter 6. For the U11-U16 squads, counter movement jumps rather than squat jump may be recommended as they showed a relationship with total distance covered during a match (Chapter 6) and were influenced by sexual maturity (Chapter 7). However, no such relationships and influences of biological maturity were found in the U17 and U18 squads even though importance of jump ability in the U17 and U18 elite soccer players were shown previously (Hulse, 2010, unpublished).

In Chapter 4, 6 and 7 of this thesis, the endurance of elite youth soccer players was examined using the Yo-Yo intermittent recovery test (level 1) and the Multi-stage fitness test. Performance on both tests improved until the players reached the U17 squad (Chapter 4) and both tests showed similar significant relationships with high intensity match running performances (Chapter 6). However, when multiple regression analysis was conducted on the U11-U16 group, only the Multi-stage fitness test performance explained a significant portion of the variance in high intensity match running performances. Moreover, the Multi-stage fitness test performance was strongly influenced by biological maturity regardless of the assessment method used to determine biological maturity. On the other hand, the Yo-Yo intermittent recovery test (level 1) performance was higher for the later maturers compared to the earlier maturers in the U17/U18s (estimated chronological age at PHV). Furthermore, in senior professional soccer players, statistically significant relationships were shown between total distance covered during a match and performance during the Yo-Yo intermittent recovery test (level 1) (Krustrup et al., 2003), whereas, the Multi-stage fitness test has been reported not to distinguish standard of soccer players in elite senior soccer players (Edward et al., 2003). Therefore, the Multi-stage fitness test is possibly a more sensitive test for distinguishing the players with different ability to cover match distances in the elite youth soccer players until they reach the U16 or older squad. Thereafter, the Yo-Yo intermittent recovery test (level 1) may become the more appropriate soccer specific endurance test for the players.

Therefore, when coaches and/or practitioners choose physical performance tests for the U9 to U18 elite soccer players, a sprint test, the Slalom agility test, the counter movement jump with arms (if there is enough time) and the Multi-stage fitness test or Yo-Yo intermittent recovery test (level 1) (depending on the age) are recommended for inclusion. For the sprint test, if there are no issues with equipment availability, a 30 m sprint with split times at 5, 10, 15 and 20 m is recommended. However, if there is a problem with the availability of equipment, only allowing for the measurement of sprint time for one distance, then a 20 m sprint is recommended for the U9 and U10 squads and a 30 m sprint is recommended for all other squads. Agility test performance was not related to match running performance in the studies reported in this thesis. However, previous research has reported the importance of agility in elite youth soccer players (Hulse, 2010, unpublished; Reilly et al., 2000) and agility was affected by biological maturity (Chapter 7) and thus inclusion of the Slalom agility test in a battery of performance test is recommended. Out of the three standing vertical jumps, the counter movement jump with arms showed the smoothest development with chronological age (Chapter 4), potentially because this jump is less technically demanding. Thus, of the three jumps the counter movement jump with arms is recommended. However, the jump test can be excluded altogether if there is a lack of time, equipment or facilities as findings from this thesis and previous literature have shown that sprint and jump performance were similarly related to match running performance (Chapter 6) and were highly related to each other (Wisloff et al., 1998). Thus, the ability to explosively generate power in sprinting and jumping is similar (Hansen et al., 2011). For an endurance test, the Multi-stage fitness test is recommended until the players reach at least the U16 age group squad. The Yo-Yo intermittent recovery test (level 1) is may be best for the oldest players in the academy as in elite senior soccer players, this test best relates to match performance (Krustrup et al., 2003). However, coaches may prefer continuity through the age groups in which case the Multi-stage fitness test should be used.

The findings from this thesis can provide support to coaches and staff in the talent identification process. The cross-sectional analysis in the first study (Chapter 4) established normative data describing how the physical characteristics and physical performance of elite youth soccer players changed from the U9 to the U18 age group. These data showed where each physical or performance attribute tended to slow down or stop in terms of development and thus coaches and staff should wait until this point to release a particular player if the player is only lacking in that particular physical attribute. Moreover, the last two studies of the thesis demonstrated that biological maturity can significantly influence physical characteristics (Chapter 7), physical performance (Chapter 7) and high intensity match running performance (Chapter 8) in elite youth soccer players. The influence of biological maturity on physical characteristics and physical performances were shown to exist until at least the U14 age group. Similarly, the influence of biological maturity on high intensity match running performance was shown to exist until the players reached the U15 squad and the influence was substantial, especially in the U12-U14 age groups. Therefore, a decision regarding entering, retaining or releasing a particular player should not be made largely based on physical characteristics, physical performance or high intensity match running performance before the player reaches at least the U15 squad, because the difference in these attributes are likely to disappear or to blur by the time the player fully or almost fully matures. Thus, there may be a higher chance of identifying a talented player who could go on to professional soccer if coaches and staff can provide players with time to develop particular physical and performance characteristics and time for the differences in high intensity match running performance as a result of maturity to disappear.

The Long-Term Athlete Development Model (Balyi and Hamilton, 2004) was established to support the development of elite sport performers and the findings from this thesis may support some of the statements contained in the model. The model stated that "one of the most important periods of motor development is between the ages of nine to 12" (Balyi and Hamilton, 2004). The findings presented in this thesis showed that the greatest changes in physical characteristics and physical performance occurred mostly in players up to the U13 age group whilst physical performance changed the most between 9 and 12 years of age (the 15, 20 and 30 m sprint tests (U11-U12), the Slalom agility test (U9-U10), the 505 agility test (U11-U12), the squat jump (U10-U12) and the counter movement jump without arms (U10-U12)) (Chapter 4). Thus, these findings support the statement in the Long-Term Athlete Development model. The U9 to U18 players in this thesis participated in regular training and competitions (three to six training sessions and one match in a week) during the season. Therefore, there is a possibility that the greatest development in physical performances observed in the U9-U12 squads was partly due to the motor development as a result of the regular training and competition during these age groups as was suggested in the model.

The Long-Term Athlete Development Model also stated that "windows of opportunity" for speed trainability occur between 13 and 15 years of age. However, the most improvement in speed was seen between the U10 and U13 squads based on 5, 10, 15, 20 and 30 m sprint performance (Chapter 4) and therefore, the findings in this thesis do not support the timing of speed trainability as stated in the model. Moreover, the model argued that "windows of opportunity" for aerobic trainability occur from onset of PHV. PHV for the players participating in the studies reported in this thesis occurred between 13 and 14 years of age and performance on the Multi-stage fitness test developed the most when the players were in the U13-U15 squads. Hence, these findings support the model. However, performance from the Multi-stage fitness test also developed substantially when the players were in the U9-U11 squads and the Yo-Yo intermittent recovery test (level) performance improved the most when the players were in the U10-U11 squads (Chapter 4). Therefore, the findings from this thesis only partially support the model on the timing of trainability in aerobic attributes and give no support to the model concerning the timing of the trainability in speed. However, the inclusion of a control group may have changed the amount of support provided by the findings from this thesis on the timing of speed and aerobic trainability. Moreover, the Long-Term Athlete Development Model did point out that variations in maturational status may influence the timing of the “window of opportunity” for aerobic trainability in adolescents. This opinion was supported by the findings from this thesis as endurance ability measured by the Multi-stage fitness test was positively influenced by biological maturity in U13-U14 age groups (Chapter 7). Additional to the points raised in the model, the findings of this thesis demonstrated that biological maturity also influences agility (Slalom agility test), jump height (counter movement jump without arms) (Chapter 7) and high speed match running performance (Chapter 8) in the U12-U14 squads. Thus, one practical application of the findings of this thesis is that coaches might consider grouping players on the basis of maturity which would enhance selection processes and would ensure optimum development by tailoring the physical training to the maturational stage of the players.

In summary this study has provided the most extensive description yet of the physical characteristics, field test performance and match performance of elite youth soccer players. In addition for the first time the effect of biological maturity (using 3 different methods of assessment) on a wide range of field tests and on match performance has been reported. The major changes in physical characteristics, field test performance and match performance between 10 and 14 years of age suggest that coaches should avoid as many selection decisions as possible during this age period, that they should take into account the fact that match distances covered at high speeds will be affected by maturity at these ages and that they should be aware that at present coaches choose to give more mature players additional pitch time which obviously gives them an advantage in terms of playing development. An enhanced awareness of these findings in the coaching community could lead to an improved development and more appropriate selection decisions for elite youth soccer players in England.

References

AANDSTAD, A., S. BERNTSEN, R. HAGEBERG, L. KLASSON-HEGGEBO and S.A. ANDERSSEN. (2006). A comparison of estimated maximal oxygen uptake in 9 and 10 year old schoolchildren in Tanzania and Norway. *British Journal of Sports Medicine,* 40, 287-292.

AL-HAZZAA, H.M., ALMUZAINI, K.S., AL-REFAEE, S.A., SULAIMAN, M.A., DAFTERDAR, M.Y., AL-GHAMEDI, A. and AL-KHURAIJI, K.N. (2001). Aerobic and anaerobic power characteristics of Saudi elite soccer players. *Journal of Sports Medicine and Physical Fitness,* 41, 54-61.

AHLER, T., BENDIKSEN, M., KRUSTRUP, P. and WEDDERKOPP, N. (2012). Aerobic fitness testing in 6- to 9-year-old children: reliability and validity of a modified Yo-Yo IR1 test and the Andersen test. *European Journal of Applied Physiology,* 112(3), 871-876.

ARNASON, A., SIGURDSSON, S.B., GUDMUNDSSON, A., HOLME, I., ENGEBRETSEN, L. and BAHR, R. (2004). Physical fitness, injuries, and team performance in soccer. *Medicine and Science in Sports and Exercise,* 36(2), 278-285.

ASTRAND, P. and RODAHL, K. (1986). *Textbook of work physiology*. New York: McGraw Hill.

ATKINSON, G., and NEVILL, A. (1998). Statistical methods for assessing measurement error (reliabilitity) in variables relevant to sports medicine. *Sports Medicine*, 26, 217–238.

AZIZ, A.R., TAN, F. and TEH, K.C. (2000). Relationship between maximal oxygen uptake and repeated sprint performance indices in field hockey and soccer players. *Journal of Sports Medicine and Physical Fitness*, 40, 195-200.

BALSOM, P.D., SEGER, J.Y., SJODIN, B. and EKBLOM, B. (1992). Maximal-intensity intermittent exercise: effect of recovery duration. *International Journal of Sports Medicine,* 13(7), 528-533.

BALYI, I. and HAMILTON, A. (2004). *Long-Term Athlete Development: Trainability in children and adolescents. Windows of opportunity. Optimal trainability.* Victoria, BC: National Coaching Institute British Columbia & Advanced Training and Performance Ltd.

BALYI, I. and STAFFORD, I. (2005). *Coaching for Long-Term Athlete Development*. Leeds: Coachwise UK.

BALYI, I. and WILLIAMS, C.A. (2009). *Coaching the young developing performer*. Leeds: Coachwise UK.

BANGSBO, J. (2005). The Yo-Yo tests. Available: www.soccerfitness.com

BANGSBO, J. and LINDQVIST, F. (1992). Comparisons of various exercise tests with endurance performance during soccer in professional players. *International Journal of Sports Medicine,* 13, 125-132.

BANGSBO, J., MARCELLO, F.I. and KRUSTRUP, P. (2008). The Yo-Yo Intermittent Recovery Test: A Useful Tool for Evaluation of Physical Performance in Intermittent Sports. *Sports Medicine*, 38(1), 37-51.

BANGSBO, J., NORREGAARD, L. and THORSOE, F. (1991). Activity profile of competition soccer. *Canadian Journal of Sports Science*, 16, 110-116.

BARBERO-ÁLVAREZ, J.C., COUTTS. A., GRANDA, J., BARBERO-ÁLVAREZ, V. and CASTAGNA, C. (2010). The validity and reliability of a GPS device to assess speed and repeated sprint ability (RSA) in athletes. *Journal of Science and Medicine in Sport,* 13(2), 232-235.

BAXTER-JONES, A.D.G. and HELMS, P.J. (1996). Effects of Training at a Young Age: A Review of the Training of Young Athletes (TOYA) Study. *Pediatric Exercise Science*, 8, 310-327.

BAXTER-JONES, A.D.G. and MAFFULLI, N. (2003). Endurance in young athletes: it can be trained. *British Journal of Sports Medicine,* 37, 96-97.

BEUNEN, G.P., MALINA, R.M., VAN'T HOF, M.A., SIMONS, J., OSTYN, M., REMSON, R. et al. (1988). *Adolescent growth and motor performance: A longitudinal study of Belgian boys*. Champaign, IL: Human Kinetics.

BLOOMFIELD, J., POLMAN, R. and O'DONOGHUE, P.G. (2004). Analysis of body composition of players of four major European leagues. *Journal of Sports Sciences,* 22(6), 525-526.

BOGDANIS, G.C., NEVILL, M.E., BOOBIS, L.H., LAKOMY, H.K. and NEVILL, A.M. (1995). Recovery of power output and muscle metabolites following 30 s of maximal sprint cycling in man. *Journal of Physiology,* 482.2, 467-80.

BRADLEY, P.S., SHELDON, W., WOOSTER, B., OLSEN, P., BOANAS, P. and KRUSTRUP, P. (2009). High-intensity running in English FA Premier League soccer matches. *Journal of Sports Sciences,* 27(2), 159-168.

BRODIE, D.A. (1981). *A Movement Analysis of Association Football Referees*. The Football League, London.

BURGESS, D.J., NAUGHTON, G. and NORTON, K.I. (2006). Profile of movement demands of national football players in Australia. *Journal of Science and Medicine in Sport,* 9(4), 334-341.

CAPELA, C., FRAGOSO, I., VIEIRA, F., CHARRUA, C., GOMES-PEREIRA, J. and MIL-HOMENS, P. (2004a). physical performance tests in young soccer players with special reference to maturation. *Journal of Sports Sciences,* 22(6), 529-530.

CAPELA, C., FRAGOSO, I., VIEIRA, F. and MIL-HOMENS, P. (2004b). Adolescent soccer players: a comparison of anthropometric and motor performance of different maturational age groups. *Journal of Sports Sciences,* 22(6), 530-531.

CAPRANICA, L., TESSITORE, A., GUIDETTI, L. and FIGURA, F. (2001). Heart rate and match analysis in pre-pubescent soccer players. *Journal of Sports Sciences,* 19(6), 379-384.

CARLING, C., BLOOMFIELD, J., NELSEN, L. and REILLY, T. (2008). The role of motion analysis in elite soccer: contemporary performance measurement techniques and work rate data. *Sports Medicine*, 38(10), 839-862.

CARLING, C., LE GALL, F., REILLY, T. and WILLIAMS, A.M. (2009). Do anthropometric and fitness characteristics vary according to birth date distribution in elite youth academy soccer players? *Scandinavian Journal of Medicine & Science in Sports,* 19(1), 3-9.

CASTAGNA, C., D'OTTAVIO, S. and ABT, G. (2003). Activity profile of young soccer players during actual match play. *Journal of Strength and Conditioning Research,* 17(4), 775-780.

CASTAGNA, C., IMPELLIZZERI, F., CECCHINI, E., ERMANNO RAMPININI, E. and BARVERO-ALVAREZ, J.C. (2009). Effects of intermittent-endurance fitness on match performance in young male soccer players. *Journal of Strength and Conditioning Research,* 23(7), 1954-1959.

CASTAGNA, C., MANZI, V., IMPELLIZZERI, F., WESTON, M. and BARBERO-ALVAREZ, J.C. (2010). Relationship between endurance field tests and match performance in young soccer players. *Journal of Strength and Conditioning Research,* 24(12), 3227-3233.

CHAMARI, K., HACHANA, Y., AHMED, Y.B., GALY, O., SGHAIER, F., CHATARD, J.C., HUE, O. and WISLOFF, U. (2004). Field and laboratory testing in young elite soccer players. *British Journal of Sports Medicine*, 38(2), 191-196.

CHAMARI, K., HACHANA, Y., KAOUECH, F., JEDDI, R., MOUSSA-CHAMARI, I. and WISLOFF, U. (2005). Endurance training and testing with the ball in young elite soccer players. *British Journal of Sports Medicine*, 39(1), 24-28.

CHIBANE, S., GUEMINI, H. and MIMOUNI, N. (2004). Somatotype of Algerian under-17 elite soccer players. *Journal of Sports Sciences,* 22(6), 534.

CHTARA, M., CHAMARI, K., CHAOUACHI, M., CHAOUACHI, A., KOUBAA, D., FEKI, Y., MILLET, G. P. and AMRI, M. (2005). Effects of intra-session concurrent endurance and strength training sequence on aerobic performance and capacity. *British Journal of Sports Medicine,* 39, 555–60.

CLARK, N.A., EDWARDS, A.M., MORTON, R.H. and BUTTERLY, R.J. (2008). Season-to-season variations of physiological fitness within a squad of professional male soccer players. *Journal of Sports Sciences and Medicine,* 7, 157-165.

COMETTI, G., MAFFIULETTI, N.A., POUSSON, M., CHATARD, J.C. and MAFFULLI, N. (2001). Isokinetic strength and anaerobic power of elite, subelite and amateur French soccer players. *International Journal of Sports Medicine,* 22(1), 45-51.

COOPER, K.H. (1978). *The aerobics Way*. Corgi, London.

COUTTS, A. and DUFFIELD, R. (2010). Validity and reliability of GPS units for measuring movement requirements in team sports. *Journal of Science and Medicine in Sport*, 13, 133–135.

DEZAN, V., SARRAF, T., RODACKI, A. and DA SILVA , S. (2004). Association between maturational stage and coach selection in young Brazilian soccer players. *Journal of Sports Sciences,* 22(6), 539.

DI SALVO, V., COLLINS, A., MACNEILL, B. and CARDINALE, M. (2006). Validation of Prozone ®: A new video-based performance analysis system. *International Journal of Performance Analysis in Sport,* 6, 108-119.

DI SALVO, V., BARON, R., TSCHAN, H., CALDERON MONTERO, F.J., BACHL, N. and PIGOZZI, F. (2007). Performance characteristics according to playing position in elite soccer. *International Journal of Sports Medicine,* 28(3), 222-227.

DI SALVO, V., GREGSON, W., ATKINSON, G., TORDOFF, P. and DRUST, B. (2009). Analysis of high intensity activity in Premier League soccer. *International Journal of Sports Medicine*, 30(3), 205-212.

DOWSON, M.N., CRONIN, J.B. and PRESLAND, J.D. (2002). Anthropometric and physiological differences between gender and age groups of New Zealand national soccer players. In: *Science and Football IV,* .Spinks, W., Reilly, T., and Murphy, A. eds, Routledge, London. pp. 63-71.

DRAPER, J.A. and LANCASTER, M.G. (1985). The 505 test: A test for agility in the horizontal plane. *Journal of Science and Medicine in Sport*, 17, 15-18.

DUFFIELD, R., REID, M., BAKER, J. and SPRATFORD, W. (2010). Accuracy and reliability of GPS devices for measurement of movement patterns in confined spaces for court-based sports. *Journal of Science and Medicine in Sport*, 15, 523–525.

DUNBAR, G.M.J. and POWER, K. (1997). Fitness profiles of English professional and semi-professional soccer players using a battery of field tests. In: T. REILLY, J. BANGSBO and M. HUGHES, eds, *Science and football 3.* London: Spon, pp. 27-31.

EDWARDS, A.M., CLARK, N. and MACFADYEN, A.M. (2003). Lactate and ventilatory thresholds reflect the training status of professional soccer players where maximum aerobic power is unchanged. *Journal of Sports Science and Medicine*, 2, 23-29.

ERIKSSON, B.O. (1980). Muscle metabolism in children – a review. *Acta Paediatrica Scandinavica*, 283 (suppl.), 20-28.

ERIKSSON, O. and SALTIN, B. (1974). Muscle metabolism during exercise in boys aged 11 to 16 years compared to adults. *Acta Paediatrca Belgica,* 28 suppl, 257-265.

FIGUEIREDO, A. J., GONC¸ C.E., COELHO E SILVA, M. J. and MALINA, R.M. (2009). Youth soccer players, 11-14 years: Maturity, size, function, skill and goal orientation. *Annals of Human Biology*, 36(1), 60-73.

FORD, P., DE STE CROIX, M., LLOYD, R., MEYERS, R., MOOSAVI, M., OLIVER, J., TILL, K. and WILLIAMS, C. (2011). The Long-Term Athlete Development model: Physiological evidence and application. *Journal of Sports Sciences*, 29, 389–402.

FOURNIER, M., RICCI, J., TAYLOR, A., FERGUSON, R., MONTPETIT, R. and CHALTMAN, B. (1982). Skeletal muscle adaptation in adolescent boys: Sprint and endurance training and detraining. *Medicine and Science in Sports and Exercise*, 14, 453–456.

FRANKS, A.M., WILLIAMS, A.M., REILLY, T. and NEVILL, A.M. (2002). Talent identification in elite youth soccer players: physical and physiological characteristics. In: *Science and Football IV,* .Spinks, W., Reilly, T., and Murphy, A., eds, Routledge, London, pp. 265-270.

GABBETT, T.J. and MULVEY, M. J. (2008). Time-Motion analysis of small sided training games and competition in elite women soccer players. *Journal of Strength and Conditioning Research*, 22(2), 543-552.

GARGANTA, J., MAIA, J. and PINTO, J. (1993). Somatotype, body composition and physical performance capacities of elite youth soccer players. In: T. REILLY, J. CLARYS and A. STIBBE, eds, *Science and Football II.* E. & F.N. SPON, pp. 292-294.

GRAVINA, L., GIL, S. M., RUIZ, F., ZUBERO, J., GIL, J. and IRAZUSTA, J. (2008). Anthropometric and physiological differences between first team and reserve soccer players aged 10–14 years at the beginning and end of the season. *Journal of Strength and Conditioning Research*, 22, 1308-1314.

GRAY, A.J., JENKINS, D., ANDREWS, M.H., TAAFFE, D.R. and GLOVER, M. L. (2010). Validity and reliability of GPS for measuring distance travelled in field-based team sports. *Journal of Sports Sciences*, 28, 1319-1325.

GREGSON, W., DRUST, B., ATKINSON, G. and SALVO, V. (2010). Match-to-match variability of high-speed activities in Premier League soccer. *International Journal of Sports Medicine*, *31*, 237-242.

HANSEN, K.T., CRONIN, J.B., PICKERING, S.L. and DOUGLAS, L. (2011). Do force-time and power-time measures in a loaded jump squat differentiate between speed performance and playing level in elite and elite junior rugby union players? *Journal of Strength and Conditioning Research*, 25(9), 2382-2391.

HARALAMBIE, G. (1982). Enzyme activities in skeletal muscle of 13-15 years old adolescents. *Bulletin Europeen de Physiopathologie Respiratoire*, 18(1), 65-74.

HELGERUD, J., ENGEN, L.C., WISLOFF, U. and HOFF, J. (2001). Aerobic endurance training improves soccer performance. *Medicine and Science in Sports and Exercise*, 33(11), 1925-1931.

HEMMINGS, S. (2006). *Physiological characteristics of the elite adolescent athlete: Effect of age and maturity.* PhD thesis.

HEWITT, A., WITHERS, R. and LYONS, K. (2007). Match analyses of Australian international women soccer players using an athlete tracking device. *Journal of Sports Science and Medicine*, 6, Suppl(10), 107.

HILL-HAAS, S.V., DAWSON, B.T., COUTTS, A.J. and ROWSELL, G.J. (2009). Physiological responses and time-motion characteristics of various small-sided soccer games in youth players. *Journal of Sports Sciences*, 27(1), 1-8.

HOFF, J., WISLOFF, U., ENGEN, L.C., KEMI, O.J. and HELGERUD, J. (2002). Soccer specific aerobic endurance training. *British Journal of Sports Medicine*, 36, 218-221.

HULSE, M. (2010). *Physical development and progression to professional soccer, of elite child and adolescent academy players.* PhD thesis.

HULSE, M., MORRIS, J.G., and NEVILL, M.E. (2012). A field-test battery for elite, young soccer players. *International Journal of Sports Medicine (In Press).*

IMPELLIZZERI, F.M., MARCORA, S.M., CASTAGNA, C., REILLY, T., SASSI, A., IAIA, F.M. and RAMPININI, E. (2006). Physiological and performance effects of generic versus specific aerobic training in soccer players. *International Journal of Sports Medicine*, 27(6), 483-492.

JANKOVIC, S., HEIMER, N. and MATKOVIC, B.R. (1993). Physiological profile of prospective soccer players. In: T. REILLY, J. CLARYS and A. STIBBE, eds, *Science and Football II.* London: E. & F.N. SPON, pp. 295-297.

JENNINGS, D., CORMACK, S., COUTTS, A.J., BOYD, L. and AUGHEY, R.J. (2010). The validity and reliability of GPS units for measuring distance in team sport specific running patterns. *International Journal of Sports Physiology and Performance*, 5, 328-341.

JONES, A.D.G. and HELMS, P. (1993). Cardiorespiratory fitness in young british soccer players. In: *Science and Football II.* Reilly, T., Clarys, J., and Stibbe, A. (Eds). pp. 298-303. London: E & FN Spon.

KOLLATH, E. and QUADE, K. (1993). Measurement of sprinting speed of professional and amateur soccer players. In: *Science and Football II.* Reilly, T., Clarys, J., and Stibbe, A. (Eds). London: E & FN Spon. pp. 31-36.

KRUSTRUP, P., MOHR, M., AMSTRUP, T., RYSGAARD, T., JOHANSEN, J., STEENSBERG, A., PEDERSEN, P.K. and BANGSBO, J. (2003). The Yo-Yo intermittent recovery test: Physiological response, reliability, and validity. *Medicine and Science in Sports and Exercise,* 35(4), 697-705.

KRUSTRUP, P., MOHR, M., AMSTRUP, T., ELLINGSGAARD, H. and BANGSBO, J. (2005). Physical Demands during an Elite Female Soccer Game: Importance of Training Status. *Medicine and Science in Sports and Exercise,* 37(7), 1242-1248.

KRUSTRUP, P., MOHR, M., STEENSBERG, A., BENCKE, J., KJÆR, M. and BANGSBO, J. (2006). Muscle and Blood Metabolites during a Soccer Game: Implications for Sprint Performance. *Medicine and Science in Sports and Exercise*, 38(6), 1165-1174.

LE GALL, F., CARLING, C., WILLIAMS, M. and REILLY, T. (2010). Anthropometric and fitness characteristics of international, professional and amateur male graduate soccer players from an elite youth academy. *Journal of Science and Medicine in Sport*, 13(1), 90-95.

LEGER, L.A., MERCIER, D., GADOURY, C. and LAMBERT, J. (1988). The multistage 20 metre shuttle run test for aerobic fitness. *Journal of Sports Sciences.* 6:93-101.

LEXELL, J., SJÖSTRÖM, M., NORDLUND, A.S. and TAYLOR, C.C. (1992). Growth and development of human muscle: a quantitative morphological study of whole vastus lateralis from childhood to adult age. *Muscle Nerve,* 15(3), 404-409.

LILLEGARD, W. A., BROWN, E. W., WILSON, D. J., HENDERSON, R. and LEWIS, E. (1997). Efficacy of strength training in prepubescent males and females: Effects of gender and maturity. *Paediatric Rehabilitation*, 1, 147-157.

MACLEOD, H., MORRIS, J., NEVILL, A. and SUNDERLAND, C. (2009). The validity of a nondifferential GPS for assessing player movement patterns in field hockey. *Journal of Sports Sciences,* 27(2), 121-128.

MALINA, R.M. (1988). Human Growth: Selected Aspects of Current Research on Well-Nourished Children. *Annual Review of Anthropology,* 17, 187-219.

MALINA, R.M., BOUCHARD, C. and BAR-OR, O. (2004a). *Growth, Maturation and Physical Activity 2nd Edition*. Human Kinetics, Champaign, Illinois.

MALINA, R.M., EISENMANN, J.C., CUMMING, S.P., RIBEIRO, B. and AROSO, J. (2004b). Maturity-associated variation in the growth and functional capacities of youth football (soccer) players 13-15 years. *European Journal of Applied Physiology,* 91(5-6), 555-562.

MALINA, R.M., PENA REYES, M.E., EISENMANN, J.C., HORTA, L., RODRIGUES, J. and MILLER, R. (2000). Height, mass and skeletal maturity of elite Portuguese soccer players aged 11-16 years. *Journal of Sports Sciences,* 18, 685-693.

MALINA, R.M., RIBEIRO, B., AROSO, J. and CUMMING, S.P. (2007). Characteristics of youth soccer players aged 13-15 years classified by skill level. *British Journal of Sports Medicine,* 41(5), 290-295.

MALINA, R.M., KOZIEL, S. and BIELICKI, T. (1999). Variation in subcutaneous adipose tissue distribution associated with age, sex, and maturation. *American Journal of Human Biology,* 11(2), 189-200.

MARKOVIC, G., DIZDAR, D., JUKIC, I. and CARDINALE, M. (2004). Reliability and factorial validity of squat and countermovement jump tests. *Journal of Strength and Conditioning Research,* 18(3), 551-555.

MAYHEW, S. R. and WENGER, H. A. (1985). Time-motion analysis of professional soccer. *Journal of Human Movement Studies,* 11, 49-52.

MCMILLAN, K., HELGERUD, J., GRANT, S.J., NEWELL, J., WILSON, J., MACDONALD, R. and HOFF, J. (2005a). Lactate threshold responses to a season of professional British youth soccer. *British Journal of Sports Medicine,* 39(7), 432-436.

MCMILLAN, K., HELGERUD, J., MACDONALD, R. and HOFF, J. (2005b). Physiological adaptations to soccer specific endurance training in professional youth soccer players. *British Journal of Sports Medicine,* 39(5), 273-277.

MING-KAI, C., LO, Y.S.A., LI., C.T. and SO, C.H. (1992). Physiological profiles of Hong Kong elite soccer players. *British Journal of Sports Medicine,* 26(4), 262-266.

MIRWALD, R. L., BAXTER-JONES, A. D., BAILEY, D. A., and BEUNEN, G. P. (2002). An assessment of maturity from anthropometric measurements. *Medicine and Science in Sports and Exercise,* 34, 689-694.

MOHR, M., KRUSTRUP, P. and BANGSBO, J. (2003). Match performance of high-standard soccer players with special reference to development of fatigue. *Journal of Sports Sciences,* 21(7), 519-528.

MOLLER, N.C., WEDDERKOPP, N., KRISTENSEN, P.L., ANDERSEN, L.B. and FROBERG, K. (2007). Secular trends in cardiorespiratory fitness and body mass index in Danish children: The European Youth Heart Study. *Scandinavian Journal of Medicine and Science in Sports,* 17, 331-339.

MUREIKA J. R. (2006). The effects of temperature, humidity, and barometric pressure on short-sprint race times. *Canadian Journal of Physics*, 84(4), 311-324.

ODETOYINBO, K. and RAMSBOTTOM, R. (1997). ‘‘Aerobic’’ and ‘‘anaerobic’’ field testing of soccer players. In: T. REILLY, J. BANGSBO and M. HUGHES, eds, *Science and Football 3.* London: Spon, pp. 21-26.

OERTEL, G. (1988). Morphometric analysis of normal skeletal muscles in infancy, childhood and adolescence. An autopsy study. *Journal of Neurological Science*, 88(1-3), 303-313.

PETERSEN, A.C., CROCKETT, L., RICHARDS, M. and BOXER, A. (1988). A self-report measure of pubertal status: reliability, validity and initial norms. *Journal of Youth and Adolescence,* 17, 117-133.

PEREIRA DA SILVA, N., KIRKENDALL, D.T., and LEITE DE BARROS NETO, T. (2007). Movement patterns in elite Brazilian youth soccer. *Journal of Sports Medicine and Physical Fitness*, 47(3), 270-5.

PFEIFFER, R. and FRANCIS, R. (1986). Effects of strength training on muscle development in prepubescent, pubescent and postpubescent males. *Physician and Sportsmedicine*, 14, 134-143.

PHILIPPAERTS, R.M., VAEYENS, R., JANSSENS, M., VAN RENTERGHEM, B., MATTHYS, D., CRAEN, R., BOURGOIS, J., VRIJENS, J., BEUNEN, G. and MALINA, R.M. (2006). The relationship between peak height velocity and physical performance in youth soccer. *Journal of Sports Sciences*, 24(3), 221-230.

PSOTTA, R. and BUNC, V. (2004). An intermittent anaerobic running test: reliability and factor validity in soccer players. *Journal of Sports Sciences*, 22(4), 557-558.

PUGA, N., RAMOS, J., AGOSTINHO, J., COSTA, O. and DE FREITAS, F. (1993). Physical profile of first division Portugese professional soccer team. In: T. REILLY, J. CLARYS and A. STIBBE, eds, *Science and Football II.* E. & F.N. SPON, pp. 40-42.

RAMPININI, E., BISHOP, D., MARCORA, S.M., FERRARI BRAVO, D., SASSI, R. and IMPELLIZZERI, F.M. (2007a). Validity of simple field tests as indicators of match-related physical performance in top-level professional soccer players. *International Journal of Sports Medicine*, 28(3), 228-235.

RAMPININI, E., COUTTS, A.J., CASTAGNA, C., SASSI, R. and IMPELLIZZERI, F.M. (2007b). Variation in top level soccer match performance. *International Journal of Sports Medicine*, 28(12), 1018-1024.

RAMPININI, E., IMPELLIZZERI, F.M., CASTAGNA, C., ABT, G., CHAMARI, K., SASSI, A. and MARCORA, S.M. (2007c). Factors influencing physiological responses to small-sided soccer games. *Journal of Sports Sciences*, 25(6), 659-666.

RAMPININI, E., SASSI, A. and IMPELLIZZERI, F.M. (2004). Reliability of heart rate recorded during soccer training. *Journal of Sports Sciences*, 22(6), 558-559.

RAMSBOTTOM, R., BREWER, J. and WILLIAMS, C. (1988). A progressive shuttle run test to estimate maximal oxygen uptake. *British Journal of Sports Medicine*, 22(4), 141-144.

RAVEN, P.B., GETTMAN, L.R., POLLOCK, M.L. and COOPER, K.H. (1976). A physiological evaluation of professional soccer players. *British Journal of Sports Medicine*, 10, 209-216.

REILLY, T. (2003). Motion analysis and physiological demands. In: T. REILLY and A.M. WILLIAMS, eds, *Science and soccer.* London: Routledge, pp. 59-72.

REILLY, T. and THOMAS, T. (1976). A motion analysis of work-rate in different positional roles of professional football match-play. *Journal of Human Movement Studies*. 2, 87-97.

REILLY, T., WILLIAMS, A.M., NEVILL, A. and FRANKS, A. (2000). A multidisciplinary approach to talent identification in soccer. *Journal of Sports Sciences*, 18(9), 695-702.

RIENZI, E., DRUST, B., REILLY, T., CARTER, J.E. and MARTIN, A. (2000). Investigation of anthropometric and work-rate profiles of elite South American international soccer players. *Journal of Sports Medicine and Physical Fitness*, 40(2), 162-169.

ROBERTON, M.A. and HALVERSON, L.E. (1988). The development of locomotor coordination: longitudinal change and invariance. *Journal of Motor Behavior*, 20(3), 197-241.

ROSCH, D., HODGSON, R., PETERSON, L., GRAF-BAUMANN, T., JUNGE, A., CHOMIAK, J. and DVORAK, J. (2000). Assessment and evaluation of football performance. *American Journal of Sports Medicine,* 28, S29-S39.

SHERAR, L.B., BAXTER-JONES, A.D., FAULKNER, R.A. and RUSSELL, K.W. (2007). Do physical maturity and birth date predict talent in male youth ice hockey players? *Journal of Sports Sciences,* 25(8), 879-886.

SHERAR, L.B., MIRWALD, R.L., BAXTER-JONES, A.D. and THOMIS, M. (2005) Prediction of Adult Height Using Maturity-Based Cumulative Height Velocity Curves. *Journal of Pediatrics*, 147(4), 508-514.

SIMMONS, C. (2005). The FA's Long-Term Player Development (LTPD) model. *Insight*, spring.

SJODIN, B. and SVEDENHAG, J. (1992). Oxygen uptake during running as related to body mass in circumpubertal boys: a longitudinal study. *European Journal of Applied Physiology*, 65(2), 150-7.

SLAUGHTER, M.H., LOHMAN, T.G., BOILEAU, R.A., HORSWILL, C.A., STILLMAN, R.J., VAN LOAN, M.D. and BEMBEN, D.A. (1988). Skinfold equations for estimation of body fatness in children and youths. *Human Biology*, 60, 709-723.

SPROULE, J., KUNALAN, C., MCNEIL, M. and WRIGHT, H. (1993). Validity of 20-MST for predicting VO2max of adult Singaporean athletes. *British Journal of Sports Medicine*, 27, 202-204.

ST CLAIR GIBSON, A., BROOMHEAD, S., LAMBERT, M.I. and HAWLEY, J.A. (1998). Prediction of maximal oxygen uptake from a 20-m shuttle run as measured directly in runners and squash players. *Journal of Sports Sciences,* 16, 331-335.

STOLEN, T., CHAMARI, K., CASTAGNA, C. and WISLOFF, U. (2005). Physiology of soccer: An update. *Sports Medicine*, 35(6), 501-536.

STROYER, J., HANSEN, L. and KLAUSEN, K. (2004). Physiological profile and activity pattern of young soccer players during match play. *Medicine and Science in Sports and Exercise,* 36(1), 168-174.

SVENSSON, M. and DRUST, B. (2005). Testing soccer players. *Journal of Sports Sciences,* 23(6), 601-618.

TAIANA, F., GREHAIGNE, J.F. and COMETTI, G. (1993). The influence of maximal strength training of lower limbs of soccer players on their physical and kick performances. In: T. REILLY, J. CLARYS and A. STIBBE, eds, *Science and Football II.* London: E. & F.N. SPON, pp. 98-103.

TANNER, J.M. (1962). *Growth at adolescence*, 2nd Edition. Oxford: Blackwell Scientific Publications.

TANNER, J.M., HEALY, M.J.R., GOLDSTEIN, H. and CAMERON, N. (2001). *Assessment of skeletal maturity and prediction of adult height (TW3 method)*. 3rd ed. London: WB Saunders.

TANNER, J. M., WHITEHOUSE, R. H. and TAKAISHI, M. (1966). Standards from birth to maturity for height, weight, height velocity, and weight velocity: British children, 1965. I. *Archives of Disease in Childhood*, 41, 454-471.

THE FOOTBALL ASSOCIATION MEDICAL AND EXERCISE SCIENCE DEPARTMENT. (2004). *Fitness Testing in Professional Football Academies: Physical Performance Testing Guidelines and Procedures.* Unpublished.

THE FOOTBALL ASSOCIATION PREMIER LEAGUE, Barclays Premier League. Available: http://www.premierleague.com/page/AcademicsPL/0,,12306~1078162,00.html [18/08, 2009].

TIRYAKI, G., TUNCEL, F., YAMANER, F., AGAOGLU, S.A., GUMUIDAD, H. and ACAR, M.F. (1997). Comparison of the physiological characteristics of the first, second and third league Turkish soccer players. In: T. REILLY, J. BANGSBO and M. HUGHES, eds, *Science and football 3.* London: Spon, pp. 32-36.

TOLFREY, K., CAMPBELL, I. G. and BATTERHAM, A. M. (1998). Aerobic trainability of prepubertal boys and girls. *Pediatric Exercise Science*, 10, 248-263.

TUMILTY, D. (1993). The relationship between physiological characteristics of junior soccer players and performance in a game simulation. In: T. REILLY, J. CLARYS and A. STIBBE, eds, *Science and Football II.* London: E. & F.N. SPON, pp. 281-286.

VAEYENS, R., MALINA, R.M., JANSSENS, M., VAN RENTERGHEM, B., BOURGOIS, J., VRIJENS, J. and PHILIPPAERTS, R.M. (2006). A multidisciplinary selection model for youth soccer: the Ghent Youth Soccer Project. *British Journal of Sports Medicine,* 40(11), 928-934.

VAN LENTHE, F.J., KEMPER, C.G. and VAN MECHELEN, W. (1996). Rapid maturation in adolescence results in greater obesity in adulthood: the Amsterdam Growth and Health Study. *American Journal of Clinical Nutrition*, 64(1), 18-24.

VENTURELLI, M., BISHOP, D. and PETTENE, L. (2008). Sprint training in preadolescent soccer players. *International Journal of Sports Physiology and Performance*, 3, 558-562.

VOSS, V. and SANDERCOCK, G. (2009). Does the Twenty Meter Shuttle-Run Test Elicit Maximal Effort in 11- to 16-Year-Olds? *Pediatric Exercise Science,* 21, 55-62.

VRIJENS, J. (1978). Muscle development in the pre and post pubescent age. *Medicine in Sport*, 11, 152-158.

WEBER, G., KARTODIHARDJO, W. and KLISSOURAS, V. (1976). Growth and physical training with reference to heredity. *Journal of Applied Physiology,* 40, 211-215.

WHITALL, J. (2003). Development of locomotor co-ordination and control in children. In: G. SAVELSBERGH, K. DAVIDS, J. VAN DER KAMP and S.J. BENNETT, eds, *Development of movement co-ordination in children: Applications in the fields of ergonomics, health sciences and sport.* London: Rutledge, pp. 251-270.

WILLIAMS, C. A., ARMSTRONG, N. and POWELL, J. (2000). Aerobic responses of prepubertal boys to two modes of training. *British Journal of Sports Medicine,* 34, 168-173.

WISLOFF, U., CASTAGNA, C., HELGERUD, J., JONES, R. and HOFF, J. (2004). Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players. *British Journal of Sports Medicine,* 38(3), 285-288.

WISLOFF, U., HELGERUD, J. and HOFF, J. (1998). Strength and endurance of elite soccer players. *Medicine and Science in Sports and Exercise,* 30(3), 462-467.

WITHERS, R.T., MARCIC, Z., WASILEWSKI, S. and KELLY, L. (1982). Match analysis of Australian professional soccer players. *Journal of Human Movement Studies*, 8, 159-176.

YAGUE, P.H. and DE LA FUENTE, J.M. (1998). Change in Height and Motor Performance Relative to Peak Height Velocity: A Mixed-Longitudinal Study of Spanish Boys and Girls. *American Journal of Human Biology,* 10, 647-660.

ZERGUINI, Y., KIRKENDALL, D., JUNGE, A. and DVORAK, J. (2007). Impact of Ramadan on physical performance in professional soccer players. *British Journal of Sports Medicine,* 41(6), 398-400.

Appendices

Appendix A

Statement of Informed Assent

The physiological characteristics and match performance of elite young soccer players

The purpose and details of this study have been explained to me.

I understand that this study is designed to further scientific knowledge and that all procedures have been approved by the Loughborough University Ethical Advisory Committee.

I have read and understood the information sheet and this assent form.

I have had an opportunity to ask questions about my participation.

I understand that I am under no obligation to take part in the study.

I understand that I have the right to withdraw from this study at any stage for any reason, and that I will not be required to explain my reasons for withdrawing.

I understand that all the information I provide will be treated in strict confidence.

I agree to participate in this study.

Your name ________________________________

Your signature ________________________________

Witness ________________________________

Date ________________________________

Appendix B

Loughborough University

HEALTH SCREEN **Name of child**…………………………...

It is important that volunteers participating in research studies are currently in good health and have had no significant medical problems in the past. This is to ensure (i) their own continuing well-being and (ii) to avoid the possibility of individual health issues confounding study outcomes.

Please complete this brief questionnaire to confirm fitness to participate:

1. **At present,** does your child have any health problem for which they are:
   - (a) on medication, prescribed or otherwise .... Yes ☐ No ☐
   - (b) attending your general practitioner........................... Yes ☐ No ☐
   - (c) on a hospital waiting list... Yes ☐ No ☐
2. **In the past two years,** has your child had any illness which required them to:
   - (a) consult your GP .... Yes ☐ No ☐
   - (b) attend a hospital outpatient department.................... Yes ☐ No ☐
   - (c) be admitted to hospital .... Yes ☐ No ☐
3. **Has your child ever** had any of the following:
   - (a) Convulsions/epilepsy.. Yes ☐ No ☐
   - *(b) Asthma... Yes ☐ No ☐
   - (c) Eczema .... Yes ☐ No ☐
   - (d) Diabetes.. Yes ☐ No ☐
   - (e) A blood disorder .... Yes ☐ No ☐
   - (f) Head injury .... Yes ☐ No ☐
   - (g) Digestive problems.. Yes ☐ No ☐
   - (h) Heart problems.. Yes ☐ No ☐
   - (i) Problems with bones or joints.................................. Yes ☐ No ☐
   - (j) Disturbance of balance/coordination......................... Yes ☐ No ☐
   - (k) Numbness in hands or feet...................................... Yes ☐ No ☐
   - (l) Disturbance of vision .... Yes ☐ No ☐
   - (m) Ear / hearing problems .... Yes ☐ No ☐
   - (n) Thyroid problems... Yes ☐ No ☐
   - (o) Kidney or liver problems .... Yes ☐ No ☐
   - (p) Allergy to nuts.. Yes ☐ No ☐

4. **Has any,** otherwise healthy, member of your family under the age of 35 died suddenly during or soon after exercise? .. Yes ☐ No ☐

If YES to any question, please describe briefly if you wish (eg to confirm problem was/is short-lived, insignificant or well controlled.)

....

....

***If YES, inhaler is needed on the day for your child to take part in the fitness test.**

5. **What is your child's ethnic origin?**
(Ethnic origin questions are not about nationality, place of birth or citizenship. They are about colour and broad ethnic group – UK citizens can belong to any of the groups indicated).

White

British ☐

Irish ☐

Any other White background ☐

(please specify)…………………

Mixed

White & Black Caribbean ☐

White & Black-African ☐

White & Asian ☐

Any other Mixed background ☐

(please specify)…………………………..

Asian or Asian British

Indian ☐

Pakistani ☐

Bangladeshi ☐

Any other Asian background ☐

(please specify)………………….

Black or Black British

Caribbean ☐

African ☐

Any other Black background ☐

Chinese or other ethnic group

Chinese ☐

Any other ☐

(please specify)………………….

6. **Do you smoke**?…………………………………………………..Yes ☐ No ☐
   No per day…………………………

7. **Do you drink alcohol**?…………………………………………..Yes ☐ No ☐
   Amount per week…………………...
   (one unit = ½ pint beer; 1 measure spirits, 1 glass wine)

Thank you for your cooperation!

Loughborough University

Appendix C

A study of the development of

'speed',
'endurance',
'agility',
jumping ability,
& the characteristics of match play in

elite young footballers

INSTITUTE OF YOUTH SPORT

Loughborough University

Purpose of the research

The purpose of this research is to investigate:-

1. how young football players (9-18 years old) develop as they age (in terms of how their 'speed', 'endurance', 'agility' and jumping ability changes with age and maturity status).

2. how the underlying physical characteristics of a young player (that is their 'speed', 'endurance', 'agility' and jumping ability) may impact on their match performance (such as how far they run, and what speeds they are able to attain and maintain during a football match).

3. whether specific physical characteristics and match performance in players is associated with progression in an academy and ultimately to professional level.

Potential benefits to the young player

With the information collected as a result of conducting the research the potential benefits for the young player are:-

1. a detailed understanding of how 'speed', 'endurance', 'agility', jumping ability and match performance changes with age and maturation in young players, and an understanding of the ways in which physical characteristics may impact on match play.

2. detailed feedback to young players about their 'fitness' and match performance.

3. the development of 'percentile' tables by age which will allow coaches and young players to see where they rank in terms of their 'speed', 'endurance', 'agility' and jumping ability compared with other players of the same age.

Written Summary of Potential Tests

Basic descriptive details (short questionnaire)

- Name of player
- Date of birth
- Ethnic origin
- Nationality
- International representative
- Playing position
- Name of school
- Post code
- Biological parents height (if available)

Measures of size and shape (anthropometric measurements)

- Height & Sitting Height
- Weight
- Skinfolds (bicep, tricep, suprailliac, subscapular) - small folds of skin are measured at specific body sites giving an indication of body composition
- Circumferences (upper arm, waist, calf and thigh girth) - these measurements give an indication of limb size
- Self-assessment of maturity - because of the substantial physical changes which individuals undergo during puberty (which can impact hugely on their physical performance) it is necessary to get some indication of maturity status.

Written Summary of Potential Tests

Field Tests (carried out at the Academy training facilities)

- **30m Timed sprints**
  - Timing gates will be placed at 5, 10, 15, 20 and 30m, and 2 sprints will be performed.
- **505 agility test**
  - Players will sprint for 10m, perform 180˚ turn and then sprint back for 5m.
- **A slalom agility test**
  - This test will measure the time taken to go through 2 gates placed 20m a part and there are 4 cones placed in zig-zag positions in the course for players to go round.
- **Vertical jump tests**
  - 3 types of standing vertical jumps will be performed on jump mat to measure the jump height.
- **Yo-Yo intermittent recovery test**
  - This test involves fast running, jogging, walking and stopping, and will continue until exhaustion. Running speed will be progressed and controlled by audio signals.
- **A 20 m multi-stage fitness test (or "bleep test")**
  - This test requires repeated 20m runs until exhaustion. Speed will be progressed and controlled by audio signals.

Match Analysis (undertaken during actual match play)

This will require players to wear a small GPS device (which sits in a pocket between the shoulder blades; the pocket is part of a harness which can be worn under the playing shirt). The GPS device accurately indicates the speed and distances being covered by a player. In combination with use of a heart rate monitor, GPS analysis can give a good indication of the match performance of young players.

Laboratory testing, where possible
(Undertaken at Loughborough University)

- Maximal aerobic power (which gives an indication of a players maximal potential for endurance exercise).
- Speed-lactate test (which gives an indication of 'endurance' training status and is sensitive to training).

When would the testing take place?

- If it would be possible to conduct laboratory tests the most useful time to undertake these assessments would be at the beginning and end of the pre-season period.
- If possible the field test measurements would be made at the end of pre-season, sometime during the season (around Christmas possibly) and at the end of the playing season.

Time required to complete the testing programme?

- For the laboratory test, players will be grouped into 2s or 3s and for a group, measuring maximal aerobic power and conducting speed lactate test would require 2–3 hours.
- The questionnaire, size and shape measurements, and the field test measurements would require 2 x 2-3 hours to complete for roughly 40 players.
- The match analysis would be carried out during 3-4 matches - more if this proved possible.

Associated Risks and Discomforts

In individuals who have a medical problem maximal exercise can be a risk to health and in extreme cases can be a cause of sudden death. However, in young active individuals the risks are minimal and all players who wish to be involved in this project will be asked to complete a health history questionnaire before they participate in any testing. If there are any reasons why maximal exercise may pose a risk to their health, players will be told not to take part in the testing procedures. Players are free to withdraw from the tests at any time without penalty or prejudice.

Confidentiality

Although information will be stored on a computer, players will be entered by a number rather than by name. All data will be stored in accordance with the Data protection Acts of 1984 and 1998.

Results will be used for research purposes and will be available to Nottingham Forest Football Club Academy coaches.

Ethical Issues

- All players and their parents should read the information sheet detailing the purpose and requirements of the testing procedures.
- All players will need to complete an informed assent.
- Parents / guardians / care-givers will need to complete a informed consent.
- All players will need to complete a health history questionnaire before any involvement in testing.

Contact Details

If you have any questions or would like any additional information, please do not hesitate to contact the researchers involved in the study:

Mr Heita Goto	e-mail: h.goto@lboro.ac.uk	tel. 01509 226 351
Dr. John Morris	e-mail: j.g.morris@lboro.ac.uk	tel. 01509 226 314

Appendix D

Parent / Guardian Consent

Study Title: The physiological characteristics and match performance of elite young soccer players

Tests involve: GPS match analysis, physical measurements, self-assessment of maturity, timed sprints, Slalom agility test, 505 agility test, vertical jump test and 2 field-based endurance run tests.

- I have been provided with an information sheet and fully understand what the tests involve
- I have been invited to observe procedures
- I have been given the opportunity to ask any questions (please see information sheet for contact details) and understand what will be required of my child
- I give permission for my child to be involved in the testing

Child's Name ______________________________

Parent / Guardian's signature ______________________________

Parent / Guardian's name (please print) ______________________________

Does your child take any medication? Yes ❑ No ❑
If yes, please explain:____

____

Does your child have a medical condition? Yes ❑ No ❑
If yes, please explain: ____

Appendix E

From: Meredith Coney [mailto:M.R.Coney@lboro.ac.uk]
Sent: 28 January 2008 14:40
To: Mary Nevill; John Morris; Heita Goto
Subject: Research Proposal R08-P7

Project title: The physiological characteristics and match performance of elite young soccer players
Proposal Number: R08-P7

Please find attached the clearance notification from the EAC with regard to the above proposal. Any changes or amendments that have been requested should be emailed.

Thank you for helping the Committee with its work

Regards

Meredith Coney

Meredith Coney
Graduation and Student Office
Administration 2
Loughborough University
Loughborough
LE11 3TU
t: +44 (0)1509 22 2468
f: +44 (0)1509 223907
e: M.R.Coney@lboro.ac.uk
w: www.lboro.ac.uk/graduation

Ref No: R08-P7

LOUGHBOROUGH UNIVERSITY

ETHICAL ADVISORY SUB-COMMITTEE

RESEARCH PROPOSAL

INVOLVING HUMAN PARTICIPANTS

Title:	The physiological characteristics and match performance of elite young soccer players
Applicant:	Dr M Nevill, Dr J Morris, H Goto
Department:	School of Sport and Exercise Science
Date of clearance:	16 January 2008

Comments of the Sub-Committee:

The Sub-Committee agreed to issue clearance to proceed subject to the following conditions:

- That confirmation was provided (under Question 13) that participants would all be male.
- That the title of the Participant Information sheet was amended to refer to "A study of" the development of elite young soccer players.
- That the Participant Information sheet was amended as follows: (i) Basic Descriptive Details section: To include a caveat (eg. "if available") to the question on biological parents height, in case of non-standard families (the Sub-Committee could envisage situations where a participant might not be in contact with his biological parents). (ii) Field Tests section: To explain in more detail, in terms understandable by parents, what was involved in 505 agility tests, and yo-yo intermittent recovery tests etc. (iii) Time Required section: To explain in more explicit terms exactly how much time each participant would be required to commit. (iv) Ethical Issues section: To replace references to "would" with "will."

ETHICAL ADVISORY COMMITTEE

Loughborough University

RESEARCH PROPOSAL FOR HUMAN BIOLOGICAL OR PSYCHOLOGICAL AND SOCIOLOGICAL INVESTIGATIONS

This application should be completed after reading the University Code of Practice on Investigations Involving Human Participants (found at http://www.lboro.ac.uk/admin/committees/ethical/ind-cophp.htm).

1. Project Title

A study of the physiological characteristics and match performance of elite young soccer players

2. Brief lay summary of the proposal for the benefit of non-expert members of the Committee

In 1998, academies were established in English professional soccer clubs with objective to develop young elite soccer players. But their physical characteristics and changes in their physical characteristics over a period of time is largely unknown. There is a cross-sectional study conducted on anthropometric measurement and physiological development of young elite players drawn from 10 English soccer academies. Data was taken from 1177 academy players and age range was from 8.3 to 17.8 years old. The results showed that peak body mass increase occurred 15.4 years of age (8.1 kg/year) and peak height velocity was recorded one year earlier. Both 10 and 20m sprint speed increased every year from 10.5 up to 15.5 years of age, but no changes were recorded in other age. This general pattern of change was also seen in the rocket jump and the counter movement jump with arms. As there is only one study conducted to measure development of physical characteristics of academy players in English professional soccer clubs that more information and details may be required. Also the relationship between fitness test results and match analysis data from academy players of an English professional soccer club need to be investigated as no such investigation has taken place at this time period.

Subjects will be **8 – 18** years old and they will be recruited from an academy of an English professional soccer club. In this study, players' anthropometric measurement and base fitness will be recorded. For anthropometric measurement, height, body weight and body fat will be recorded. Base fitness will include players' 10 and 20m speed, agility, standing vertical jumps and estimated VO_2max. Standing vertical jumps include Rocket jump, Counter movement jump with and without arms. All of fitness tests will be conducted in indoor Astroturf.

For match analysis, participants in the study will be asked to wear a Global Positioning System (GPS) device during matches. The GPS is a device which can be used to monitor player activity (including distance travelled and speed) during competitive play, with greater accuracy than was previously possible. The relationship between fitness test results and match analysis data will then be investigated.

3. **Details of responsible investigator (supervisor in case of student projects)**

Title	Mrs.	Surname	Mary	Forename	Nevill

Department School of Sports and Exercise Sciences

Email address M.E.Nevill@lboro.ac.uk

Personal experience of proposed procedures and/or methodologies.

Over 20 years experience of laboratory exercise testing and research in exercise physiology

4. **Names, experience, department and email addresses of additional investigators**

Dr. John G. Morris
J.G.Morris@lboro.ac.uk
Research Associate,
School of Sport and Exercise Sciences,
Trained to undertake listed procedures with 11 years experience in laboratory exercise testing.

Mr. Heita Goto
H.Goto@lboro.ac.uk
PhD Student
School of Sport and Exercise Sciences,
Trained to undertake listed procedures with 3 years experience in laboratory exercise testing.

5. **Proposed start and finish date and duration of project**

Start date	July 2007	Finish date	May 2010	Duration	2 years and 11 months
Start date for data-collection		23rd July 07			

NB. Data collection should not commence before EAC approval is granted.

6. **Location(s) of project**

Laboratory, School of Sport and Exercise Sciences, Loughborough University, Leicestershire, LE11 3TU

Professional Football Club academy

7. **Reasons for undertaking the study (eg contract, student research)**

Student research for partial fulfilment of PhD (Heita Goto)

8. Do any of the investigators stand to gain from a particular conclusion of the research project?

No

9a. Is the project being sponsored? **Yes** [ ] **No** [x]

If yes, please state source of funds including contact name and address.

9b. Is the project covered by the sponsors insurance? **Yes** [ ] **No** [x]

If no, please confirm details of alternative cover (eg University cover).

University cover

10. Aims and objectives of project

Aim is to investigate characteristics of physical development of **U-9 to U-18 soccer** players in academy of professional soccer club in England

11. Brief outline of project

Young elite soccer players recruited from academy of English professional soccer club will undergo a series of assessments including analysis of activity during a competitive match using a Global Positioning System (GPS), anthropometric assessment, self assessment of sexual maturity and a number of field-based tests designed to assess aerobic fitness, agility, jump ability and speed. Also laboratory tests will be conducted to measure lactate threshold and maximal oxygen uptake. Individual player performance in the laboratory and field tests will be compared with performance in a competitive game.

A) STUDY DESIGN

Cross sectional and longitudinal

B) MEASUREMENTS TO BE TAKEN

1. **Match Analysis**
   To determine individual player activity during a series of competitive matches (i.e. distance covered, acceleration/deceleration) players will each wear a portable GPS device. The equipment used is small (91 x 45 x 21 mm) and light (75 g) and is fitted to a lightweight harness on the player's back where it should not interfere with the individual's play. Data colleted during the match will then be downloaded to a computer for analysis.

2. **Laboratory Testing**
   (a) Lactate threshold
   This measurement includes a protocol of 4 min x 4 stages of running on motorised treadmill. The speed will start from 11.2

km/hour and will be increased by 1.6 km/hour every stage. After completing each stage, finger prick blood sample will be taken from the subjects.

(b) Maximal oxygen uptake test

This test requires a subject to run till exhaustion on motorised treadmill. Expired air samples using Douglas bag will be taken between 1:45 min and 2:45 min, and also at every third minute after the first collection until subjects exhaust. Moreover, expired air sample will be taken at final minute where the subject can sustain the exercise intensity. The treadmill will be inclined for 3% at the start and after every expired air sample, inclination will be increased by 2%. Running speed will be decided according to HR data obtained during lactate threshold measurement.

(c) Anthropometric Assessment

Standard procedures will be used to obtain height, body mass, skinfold thickness, thigh girth and calf, upper arm and waist circumference measurements.

(d) Self-assessment of secondary sex characteristics

To provide an indication of maturity status participants complete a self-assessment of physical characteristics. Participants will rate their pubic hair, genitalia (male) and breast (female) development using standards which have been in clinical use for more than 40 years. The self-assessments are conducted in complete privacy. The participant records their rating on an form and seals it within an envelope. All information obtained is treated with the strictest confidence.

3. **Field Testing**

The following field tests will be completed by participants over two 3 hours sessions:

(a) 3 types of standing vertical jumps using jump mat
(b) 2 Agility tests using time gates
(c) **Timed 30 m sprints**.
(d) A continuous 20 m multi-stage shuttle run test to predict maximal oxygen uptake (Ramsbottom et al, 1994). The test takes around 20 minutes to complete.
(e) Yo-yo intermittent recovery test to predict intermittent endurance ability. The test lasts for 15-25 min.

12. Please indicate whether the proposed study:

Involves taking bodily samples	**Yes**		**No**	**x**
Involves procedures which are physically invasive (including the collection of body secretions by physically invasive methods)	**Yes**	**x**	**No**	
Is designed to be challenging (physically or psychologically in any way), or involves procedures which are likely to cause physical, psychological, social or emotional distress to participants	**Yes**	**x**	**No**	

Involves intake of compounds additional to daily diet, or other dietary manipulation / supplementation	**Yes**		**No**	**X**
Involves pharmaceutical drugs (please refer to published guidelines)	**Yes**		**No**	**X**
Involves testing new equipment	**Yes**		**No**	**X**
Involves procedures which may cause embarrassment to participants	**Yes**	**x**	**No**	
Involves collection of personal and/or potentially sensitive data	**Yes**	**x**	**No**	
Involves use of radiation (Please refer to published guidelines. Investigators should contact the University's Radiological Protection Officer before commencing any research which exposes participants to ionising radiation – e.g. x-rays)	**Yes**		**No**	**x**
Involves use of hazardous materials (please refer to published guidelines)	**Yes**		**No**	**x**
Assists/alters the process of conception in any way	**Yes**		**No**	**x**
Involves methods of contraception	**Yes**		**No**	**x**
Involves genetic engineering	**Yes**		**No**	**x**

If Yes - please give specific details of the procedures to be used and arrangements to deal with adverse effects.

Exercise Tests

Vigorous exercise will cause breathlessness and temporary fatigue. Any vigorous exercise results in an increase in the risk of a cardiovascular emergency above that present at rest. To identify any risk, participants are required to complete a health questionnaire prior to undertaking any exercise. This risk is very small for individuals not exhibiting risk factors for coronary heart disease. During testing investigators are, at all times, vigilant in their observations of participants performing under the prescribed experimental conditions and are ready to end any testing should the participant report, or even appear unduly stressed. Also the players who will participate in this research will be accustomed to vigorous exercise.

Potential embarrassment to participants

Self-assessment of secondary sex characteristics may cause embarrassment to the participants. However, the requirements of the assessment will be explained to the participant alone in private by the tester before allowing the participant to make the assessment alone in an enclosed room. Subjects are ensured that all information will be treated with the strictest confidence.

Personal and/or potentially sensitive data

All data will be computerised and each participant will be entered as a number rather than a name. Participants will be made aware that all data is treated with confidence and will be stored in accordance with the Data Protection Act.

13. Participant Information

Details of participants (gender, age, special interests etc)

8 – 18 years old male soccer players from an English professional football club Academy

Number of participants to be recruited: 90-150

How will participants be selected? Please outline inclusion/exclusion criteria to be used.

Only players from English professional football club Academy players are involved

How will participants be recruited and approached?

Players will be approached through coaching staff

Please state demand on participants' time.

4 – 5 hours in every 6 months

14. Control Participants

Will control participants be used? **Yes** [ ] **No** [**x**]

If Yes, please answer the following:

Number of control participants to be recruited:

How will control participants be selected? Please outline inclusion/exclusion criteria to be used.

N/A

How will control participants be recruited and approached?

N/A

Please state demand on control participants' time.

N/A

15. Procedures for chaperoning and supervision of participants during the investigation

The children will be tested in at least pairs. At no other time, apart from the explanation of the maturity assessment, will one young person be left alone with the researcher. It must be noted that all experimenters are CRB checked. At all other times, there will be at least two researchers present, one of these will be of the same sex as the participant being tested The young subjects will be weighed in shorts and t-shirt. Clothing does not need to be removed for any test, although it may be lifted for example for placement of heart rate monitor and for skin-fold measurements. Anthropometric measures will be taken by a member of the staff trained to undertake the task.

16. Possible risks, discomforts and/or distress to participants

High intensity treadmill exercise will cause breathlessness and temporary fatigue . The maximum oxygen uptake test will lead to physical exhaustion, but participants should recover within a few minutes. In a tiny minority of individuals, even in young adults, the possibility exists that such exercise triggers disturbances to normal physiology: including abnormal blood pressure, fainting or a change in the normal rhythm of the heart. There are also risks associated with performing exercise including musculoskeletal injury but these are minimal and measures will be taken to prevent any occurrences.

17. Details of any payments to be made to the participants

N/A

18. Is written consent to be obtained from participants? **Yes** [x] **No** [ ]

If yes, please attach a copy of the consent form to be used.

If no, please justify.

19. Will any of the participants be from one of the following vulnerable groups?

Children under 18 years of age	**Yes**	**x**	**No**	
People over 65 years of age	**Yes**		**No**	**x**
People with mental illness	**Yes**		**No**	**x**
Prisoners/other detained persons	**Yes**		**No**	**x**
Other vulnerable groups	**Yes**		**No**	**x**

If you have selected yes to any of the above, please answer the following questions:

a) what special arrangements have been made to deal with the issues of consent?

Parental or guardian's consent in addition to the written and informed "assent" child will be sought prior to testing. Special care will be taken to explain all procedures in a manner using terminology suitable for the child. It will be emphasised to the child that at any time they may withdraw with no negative repercussions. Parents or guardians will invited to accompany the child during testing.

b) have investigators obtained necessary police registration/clearance? (please provide details or indicate the reasons why this is not applicable to your study)

All named investigators are CRB checked

20. How will participants be informed of their right to withdraw from the study?

Participants will be informed of the right to withdraw both verbally and in writing

21. Will the investigation include the use of any of the following?

Audio recording	**Yes**		**No**	**x**
Video recording	**Yes**		**No**	**x**
Observation of participants	**Yes**		**No**	**x**

If yes to any, please provide detail of how the recording will be stored, when the recordings will be destroyed and how confidentiality of data will be ensured?

22. What steps will be taken to safeguard anonymity of participants/confidentiality of personal data?

Each participant will be assigned an identification code under which all associated data will be stored on a computer. Data will therefore not be identifiable by name.

23. What steps have been taken to ensure that the collection and storage of data complies with the Data Protection Act 1998? Please see University guidance on Data Collection and Storage and Compliance with the Data Protection Act.

Participants will be assigned a reference code so that a set of data or blood samples cannot be related back to any individual in order to ensure confidentiality of data collected during the study.

Investigators will ensure that any results of the study that are published do not allow individuals to be identified directly or indirectly.

24. INSURANCE COVER:

It is the responsibility of investigators to ensure that there is appropriate insurance cover for the procedure/technique.

The University maintains in force a Public Liability Policy, which indemnifies it against its legal liability for **accidental** injury to persons (other than its employees) and for accidental damage to the property of others. Any **unavoidable** injury or damage therefore falls outside the scope of the policy.

Will any part of the investigation result in **unavoidable** injury or damage to participants or property?	**Yes**		**No**	**x**

If yes, please detail the alternative insurance cover arrangements and attach supporting documentation to this form.

The University Insurance relates to claims arising out of all **normal** activities of the University, but Insurers require to be notified of anything of an unusual nature

Is the investigation classed as **normal** activity?	**Yes**	**x**	**No**	

If no, please check with the University Insurers that the policy will cover the activity. If the activity falls outside the scope of the policy, please detail alternative insurance cover arrangements and attach supporting documentation to this form.

25. Declaration

I have read the University's Code of Practice on Investigations on Human Participants and have completed this application. I confirm that the above named investigation complies with published codes of conduct, ethical principles and guidelines of professional bodies associated with my research discipline.

I agree to provide the Ethical Advisory Committee with appropriate feedback upon completion of my investigation.

Signature of applicant: ....

Signature of Head of Department: ....

Date ....

PLEASE ENSURE THAT YOU HAVE ATTACHED COPIES OF THE FOLLOWING DOCUMENTS TO YOUR SUBMISSION.

- Participant Information Sheet
- Informed Consent Form
- Health Screen Questionnaire*
- Advertisement/Recruitment material*
- Evidence of consent from other Committees*

*where relevant

Appendix F

Dear Parents / Guardians / Care-givers

The Institute of Youth Sport (School of Sport and Exercise Sciences) at Loughborough University is conducting research investigating how the physical characteristics and match performance of young football players changes as they grow older and mature. The research requires players to undertake various physiological tests, at their football club and, where possible, in a laboratory at Loughborough University. Players will also be required to wear a small global positioning satellite (GPS) device during matches, which allows assessment of the distances they move and the speeds at which they do so. Hopefully it will prove possible to conduct the tests at the football club 3/4 times during a year, the tests in the laboratory 1/2 times per year and the GPS match analysis on at least 3-4 games in a season.

We would really like your son to be part of this research. Please read the enclosed information pack for a more detailed explanation of the testing and match analysis procedures, and if you are then willing for your son to become involved then return the 'informed assent', 'informed consent' and 'health screen questionnaire' to us or the coaches at the club.

The Loughborough University staff overseeing the research will ensure that the fitness testing is safe, enjoyable and educational, and all staff are Criminal Records Bureau (CRB) checked. The guidelines we follow meet the strict ethical standards that are set out by Loughborough University. All participants will receive feedback of their results.

If you have any further questions, please contact Dr. John Morris or Mr. Heita Goto on the number below.

Yours sincerely,

Heita Goto

Mr. Heita Goto
Researcher
School of Sport and Exercise Sciences
Loughborough University
Leicestershire
LE11 3TU

Dr. John Morris
Institute of Youth Sport
School of Sport and Exercise Sciences
Loughborough University
Leicestershire
LE11 3TU

If further information is required, please contact either:

Dr. John Morris j.g.morris@lboro.ac.uk Tel. 01509 226314
Mr. Heita Goto h.goto@lboro.ac.uk Tel. 01509 226352

Appendix G

Dear Parents / Guardians / Care-givers

Staff from the Institute of Youth Sport, Loughborough University, in collaboration with the Nottingham Forest Football Academy will be conducting series of fitness testing sessions in October 2010 and we would like your son to participate again provided he is happy, and you are willing for him to do so. As you and your son have completed consent and assent forms previously, only completion of a health screen questionnaire is necessary for him to take part in the forthcoming fitness testing sessions. Please complete the health screen questionnaire enclosed and return it to us or the coaches at the club.

If you have any questions, please contact Dr. John Morris or Mr. Heita Goto on the number below.

Yours sincerely,

Heita Goto

Mr. Heita Goto	Dr. John Morris
Researcher	Institute of Youth Sport
School of Sport and Exercise Sciences	School of Sport and Exercise Sciences
Loughborough University	Loughborough University
Leicestershire	Leicestershire
LE11 3TU	LE11 3TU

If further information is required, please contact either:

Dr. John Morris	j.g.morris@lboro.ac.uk	Tel. 01509 226314
Mr. Heita Goto	h.goto@lboro.ac.uk	Tel. 01509 226352