Normative values of functional competence, speed and lower body power for youth football players at different stages of biological maturity.

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A dissertation submitted in fulfilment of the requirement for the Master of Arts in Strength and Conditioning

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Submitted to Waterford Institute of Technology

May 2016

Statement of Originality and Ownership of Work

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I confirm that all the work submitted in this dissertation is my own work, not copied from any other person's work (published or unpublished) and that it has not been previously submitted for assessment on any other course, in any other institution.

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Acknowledgements

I would like to thank Waterford Institute of Technology for allowing me to enrol on this research masters and for the parents and elite academy players for taking part in this study.

Thanks to my tutor Gerry Fitzpatrick for his experience and guidance on this project.

Finally I wish to express my deepest gratitude to the person closest to me; my wife Lara, for patience and love through the entire process.

Contents

List of Tables

Lists of Graphs

List of Figures

Operational Definitions

Childhood: Represents the development period of life from the end of infancy to the beginning of adolescence. The term children refer to girls and boys (generally up to the age of 11 years and 13 years respectively) who have not developed secondary sex characteristics.

A**dolescence:** Refers to a period of life between childhood and adulthood. Although adolescence is a more difficult period to define in terms of chronological age due to differential maturation rates, girls 12-18 years and boys 14 to 18 years are generally considered adolescents.

Y**outh:** This is a global term which includes both children and adolescents.

Growth: This is typically viewed as a quantifiable change in body composition, the size of the body as a whole, or the size of specific regions of the body.

Maturation: Refers to the highly variable timing and tempo of progressive change within the human body from childhood to adulthood, and which, in addition to growth, influences overall physical performance capabilities. (Lloyd, et al. 2012)

Development: Refers to "the interrelationship between growth and maturation in relation to the passage of time. The concept of development also includes the social, emotional, intellectual, and motor realms of the child."

Peak Height Velocity (PHV): This is the maximum rate of growth in stature during the pubertal growth spurt. The age of maximum velocity of growth is called the age at PHV. (Balyi, et al. 2011)

Pre pubertal Growth Spurt: This is the period of childhood before the onset of Peak Height Velocity. Using the Khamis Roche method, it is classified as youths at 88% of adult height or below.

Pubertal Growth Spurt: This is the period of the accelerated growth from the onset of Peak Height Velocity to the point of a reduction in accelerated growth. Using Khamis Roche method, it is classified as youths between 89% and 95% of adult height.

Post Pubertal Growth Spurt: This is the period after the Pubertal Growth Spurt. Using Khamis Roche method it is youths at 96% or above. (Khamis H.J. & Roche A.F. 1994)

Abstract

Professional football clubs place great emphasis on development of young players to attain first team squad membership, yet despite extensive research on senior teams there is limited knowledge the assessment of functional competence and the development of elite youth players (Brownlee, et al. 2015). This study aimed to assess normative values of functional competence, speed and lower body power for elite youth players at different stages of biological maturity as these factors have significant value in the planning and implementation of football specific training programmes (Lloyd, et al. 2014). One hundred and thirty male soccer players (n=130) from 7 different age groups within an Elite English Premier League Academy participated in the study. Participants were assessed using the countermovement jump test, 0 to 10 meter speed test and the FMS (Cook, et al. 2006). Percentage of adult height was attained using the Khamis-Roche method (Khamis & Roche, 1994). Subjects were classified as Pre pubertal growth spurt when assessed to be 89% or less of predicted adult height, during pubertal growth spurt when between 89% and 95% of predicted adult height and Post pubertal growth spurt when past 95% of adult height. The Pre pubertal growth spurt group had forty six subjects (n=46), the Pubertal Growth Spurt group had thirty six participants (n=36), and the Post Pubertal growth spurt group had forty eight subjects (n=48).

Results indicated that during the Pre Pubertal Growth Spurt there is a correlation between speed and power ($r = -.706$) but not between speed and FMS ($r = -.233$) or between jump and FMS ($r = .126$) results. The Pubertal Growth Spurt group showed a correlation with speed and jump ($p = -.587$) and FMS and jump ($r = .465$) but found no correlation with speed and FMS ($p = -.264$). There were correlations with all three elements in the final post pubertal growth spurt stage. FMS and Jump ($r = -.341$), jump and speed ($r = -.585$) and FMS and speed ($r = .521$). The study concluded that functional competence and movement pattern ability follow different developmental patterns to speed and power and that the higher the FMS score the greater the chance of positive longitudinal performance change in areas such as speed and power. There are also implications for the planning and implementation of football specific, maturational appropriate, training programmes.

Chapter 1

Introduction

Professional football clubs place great emphasis on training young players to reach the level of their first team squads, (Brownlee, et al. 2015). However despite extensive research on senior teams there is limited knowledge about the training and development of youth players. Brownlee, et al. (2015) highlighted the need for greater research into the type and development of training in the professional academy system. In addition to the necessary technical and tactical skills required, football players must develop and retain a high level of athleticism to be successful. Previous research identified that aerobic endurance, ability to repeatedly execute high-intensity actions, speed, agility, strength, power are all determinants of superior performance (Reilly T, Bangsbo J, and Franks 2000). Over the course of the game players must accelerate and decelerate rapidly, jump, bound, and leap repeatedly. Players must maintain the ability to accelerate, decelerate, and change direction for the entire duration of the 90 minute match while maintaining soccer specific skills, (Reilly, 1997). Therefore, speed and power are important components of soccer-specific fitness training (Jakobsen, et al. 2012). All of these motor skills and functional movements require players to efficiently generate large quantities of force over short periods of time (Thorlund et al., 2009).

Numerous methods for assessing functional competence exist. One popular method that has been examined in the literature is the Functional Movement Screen (FMS). The functional movement screen was originally designed to assess muscle flexibility, strength imbalances and general movement proficiency in a range of performance tests; identify functional deficits related to proprioception, mobilisation and stabilisation; and determine the existence of pain during any of the prescribed movement patterns (Cook, Burton, & Hoogenboom, 2006b). The screen can be used to assess the functional competence and thus movement pattern of a player and this will help evaluate if the player can progress to more advanced exercises that can aid performance and development (Cook, et al. 2010). Success of football academies can hinge on correct identification, selection of and development of players (Hornig, et al. 2016). There are many confounding factors in the prediction of future talent and the current Elite Player Performance Programme initiative (Premier League website, 2016) has been a significant step in this process. Researchers have recently advocated that talent development programmes in sports should be dynamic while accounting for biological maturity status, relative age effect (where there is a bias towards the players born in the earlier months of a competition year) and maintain the potential to develop rather than exclude children at an early age (Meylan, et al. 2010).

The relationship between maturity, functional competence, speed and power have significant value in the planning and implementation of football specific training programmes, and form the basis of this investigation as well as attempting to establish normative values for a specific group of players (Lloyd, et al. 2014).

With increasing demands on athletes and teams to perform to the upper level of their capabilities on a more consistent basis, a clear philosophy about the approach to training is crucial (Bergeron, et al. 2014). A number of issues are worthy of debate in particular those relating to reducing the risk of injury, using an integrated approach to training, and being concerned about the functional competence and movement abilities of athletes. Proper use of corrective exercise strategies can assist athletes in all these areas as well as creating a good setting for greater gains in the development of skill and the training of physical capacities (Comerford, 2001). This process is even more challenging in the team sport environment where larger numbers of athletes and more congested competition schedules place an added burden on coaches and trainers. However if we are to acknowledge that the body is a kinetic chain (Clark, 2004) and weaknesses in muscle balance will eventually, if not imminently lead to biomechanical inefficiency and a reduction in the performance capabilities of the athlete, then the greater emphasis strength and conditioning coaches must place in the preparation of athletes for more intensive training and extended period of injury free performances. It is of upmost importance that athletic development programmes are individualised, position specific and biological stage specific. As we collect more information on the child and youth player this will lead to enhanced decision making on programme design.

Chapter 2

Literature Review

Biological maturation is considered in the literature more appropriate guide than chronological age in the prescription of young athlete's strength and conditioning programmes, primarily due to the variation in development within the same chronological age in young players (Vandendriessche, et al. 2011). Variability exists between individuals of the same chronological age in biological maturity and is particularly accentuated around the adolescent growth spurt (Milina et al., 2004). It is imperative that all prospective studies in children, both in the context of youth sport classification and research investigations, attempt to control for maturity (Mirwald, et al. 2002). Interest in youth strength and conditioning has increased dramatically over the last number of years resulting in the publication of the Youth Resistance Training: Updated Position Paper from the National Strength and Conditioning Association (NSCA) (Faigenbaum, et al. 2009) and the United Kingdom Strength and Conditioning Association (UKSCA) Position Statement on Youth Resistance Training (Lloyd, et al. 2012). Both associations recognize and promote the benefits of resistance training for youths and recommend that further investigation is warranted on the normative values at different stages of biological maturation.

There has been a surge in interest by scientists and coaches in the area of long term athlete development (Balyi & Hamilton, 2004, Lloyd & Oliver 2012, Gublin, et al. 2013 & Lloyd, et al. 2015). The widest use of these models is The Long Term Athlete Development Model (Balyi & Hamilton, 2004), and it takes into consideration the maturational status of the child and offers a targeted holistic approach to the athletic development of the youth. Long Term Athlete Development (LTAD) is underpinned by the following 10 key factors (Balyi & Hamilton, 2004);

1) The Fundamentals, 2) Specialisation, 3) Development Age, 4) Trainability, 5) Holistic Development, 6) Periodisation, 7) Competition, 8) System Integration & Alignment, 9) Continuous Development and 10) Excellence takes time.

For the purpose of the study the key factor investigated was development age, specifically looking at the area of biological maturation. Children grow and develop at different rates and strength and conditioning specialists need to take this into consideration when designing appropriate training programmes (Lloyd, et al. 2015). In order to develop youth players optimally generic training programmes should not be prescribed and the development age of youth players must be considered (Lloyd, et al. 2015). It is also suggested that the increase in stature during the pubertal growth spurt which can lead to a concept termed "adolescent awkwardness" (Philippaerts et al., 2006). The term developmental age refers to how growth and maturation occur together over time. LTAD advocates the use of developmental age which refers to the youth athlete's physical, mental, emotional and intellectual maturity. LTAD recommends the identification of early, average and late developers in order to help to design appropriate training and competition programmes for each athlete (Balyi & Hamilton, 2004). This study examined biological maturation but mental and emotional maturation were beyond the scope of this research. Consequently the stage of biological maturation is particularly important to optimise the physical development programme design for the youth player.

2.1 Maturation

The literature suggests that identification of Peak Height Velocity (PHV) can reflect individual maturation (Malina, et al. 2004). LTAD suggests that a method of categorising the different stages of development in youth players is pre pubertal growth spurt, pubertal growth spurt and post pubertal growth spurt (Lloyd & Oliver 2012 and Balyi & Hamilton, 2004). Emphasis is placed on the assessment of biological maturity because it is suggested that there are various components of fitness that go through rapid development and other components that possibly regress during this period (Philippaerts, et al. 2006). Understanding the biological maturity stage of the youth player can help maximise a training programme. It is important to note that all elements of fitness can be developed with appropriate training programmes (Lloyd & Oliver, 2012), however some elements of fitness are more sensitive to change at different stages of biological maturation (Lloyd & Oliver, 2012). At the onset of puberty a rapid increase in the rate of growth and increases in muscular strength are experienced (Parker, et al. 1990). The increase in stature during the pubertal growth spurt can also lead to a concept termed "adolescent awkwardness" (Philippaerts, et al. 2006). Assessment of maturity during the childhood and adolescent period therefore is important to prescribe the most appropriate physical development programme for the youth player. Normative values at the different stages of development will also help in the prescription of an appropriate programme for youth players. Biological maturation refers to the progress towards a mature state, and it is suggested that there exists significant inter-individual differences in the magnitude, onset and rate of change of various biological components as a result of maturational processes when children are grouped according to chronological age (Malina, Bouchard, & Bar-Or, 2004). Whilst skeletal age or sexual maturation has previously been used within the literature to determine the stage of biological maturation within an individual or groups of individuals, these techniques are often inappropriate, unrealistic or possess ethical concerns (Malina, et al. 2004). Consequently, researchers used a surrogate of biological maturation by quantifying a range of somatic measures (Malina, et al. 2004). Percentage of mature height attained at a given age has been used as a maturity indicator in analyses of longitudinal growth records (Malina, et al. 2007). By inference, percentage of predicted mature height attained at a given age may serve as a maturity indicator among youth players. Methods for the prediction of mature adult height typically include an assessment of skeletal age (Malina, et al. 2004), but it is also possible to predict mature height independent of skeletal age (Malina, et al. 2007). Protocols for the prediction of mature height include current age, height, and weight of the child and midparent height in boys and girls (Khamis and Roche, 1994). The Khamis-Roche protocol was developed on the sample of the Fels Longitudinal Study in south central Ohio. The medium error bound (median absolute deviation) between actual and predicted mature height at 18years of age is 2.2cm in males (Khamis and Roche, 1994). Current height, in turn can be expressed as a percentage of the predicted value to provide an estimate of maturity status. The method provides a potentially usefully maturity indicator that has minimal physical and/or psychological risk. Percentage of predicted mature height based on current age, height and weight, and midpoint height of parents has been shown to be a reasonably valid estimate of biological maturity status in a sample of youth footballers (Malina, et al. 2007).

Whilst the limitations of somatic measures are noted, they do offer a non-invasive and more realistic approach to determining maturity status, especially within field-based environments (Malina, et al. 2015). Early paediatric research that focused on children suggested that both stature and muscular strength account for up to 70% of the variability in a range of motor skills inclusive of throwing, jumping and sprinting in 7 to 12 year old boys (Teeple, Lohman, Misner, Boileau, & Massey, 1975). It is also acknowledged that biological maturation influences physical performance, largely owing to alterations in hormonal profiles, increases in lean body mass, myelination of motor neurons and enhanced inter and intramuscular coordination (Faigenbaum, Lloyd & Myer, 2013; Lloyd, et al. 2014). All of these factors lead to the development of a number of physical and physiological variables (Malina, et al. 2004). The rapid increases in body dimensions and limb lengths and the significant development of muscle mass associated with maturation, indicate that the determination of movement proficiency during this stage of development may be affected as adolescents learn to move with fluctuating levels of coordination (Quatman-Yates, Quatman, Meszaros, Paterno, & Hewett, 2012). Therefore, the assessment of movement proficiency and fitness capacity should be viewed as an essential factor in youth physical development programmes. These assessments, performed with the consideration of biological maturation may further enhance the importance of movement proficiency and movement patterns in maturing youth players.

2.2 Functional Competence

It has been noted that the necessity of movement proficiency for safe and effective long term physical development and performance in youth athletes is of upmost importance (Lloyd & Oliver, 2012: Valovich-McLeod, et al. 2011). Poor movement proficiency during landing and cutting can predispose young athletes to an increased risk of injury (Hewett et al., 2005; Myer et al., 2009). Muscular imbalances are also an injury risk factor for youth athletes (Lehance, Binet, Bury & Croisier, 2009), and this emphasises the importance of assessing and developing the movement patterns of youth players. It has been suggested that a deficiency in age-related motor skill performance may lead to a "proficiency barrier" that could impede progression to the learning of more complex movement patterns (Seefeldt, 1980). Numerous methods for assessing movement patterns exist. One popular method that has been evaluated in the literature is the Functional Movement Screen (FMS). Research conducted (Cook, et al. 2010) has added to the support of the screening tool. FMS was originally designed to assess, muscle flexibility, strength imbalances and general movement pattern proficiency in a range of performance tests; identify functional deficits related to proprioception, mobilisation and stabilisation; and determine the existence of pain during any of the prescribed movement patterns (Cook, Burton, & Hoogenboom, 2006b). Current research on the FMS suggests that the test is a reliable way to objectively measure fundamental movement patterns (Cook, et al. 2010). Reliability of the FMS has been established between and within testers across multiple studies examining the screen (Minick, et al. 2010; Frohm, et al. 2011; Onate, et al. 2012; Teyhen, et al. 2012). Existing data suggest that the FMS demonstrates moderate-to-excellent inter- and intra-rater agreement (kappa statistic ≥60%) for most of the assessment protocols (Teyhen, et al. 2012), and as a screening tool it is routinely used within both the field and clinical settings. These studies have shown high reliability between trained FMS testers using videotaped as well as face to face scoring methods. The FMS test is recommended for fundamental screening purposes and corrective exercise prescription and can be used reliably between individuals who are trained on the screen. It is also noted that mobility and stability extremes are assessed in the FMS in order to uncover asymmetries and low competence. The scoring system was designed to capture major competency issues and right-left asymmetries related to functional movement. Additionally, clearing tests were added to assess if pain is present when the athlete completes full spinal flexion and extension and shoulder internal rotation/flexion (Kiesel, 2007: Cook, et al. 2010).

Normative values on the FMS have been published in active adult populations (Schnieders, et al. 2011). There are a small number of studies that looked at youth populations one conducted by Duncan and colleagues (2012). They reported that both BMI and physical activity were predictors of FMS scores in elementary aged children; however, BMI was the more dominant of the factors. Another study looked at the relationship between the FMS scores, maturation and physical performance in young players. It did not however compare difference stages of biological maturation. This study showed that the Functional Movement Screen is appropriate and reliable for the youth football population (Lloyd, et al. 2014). Other studies using the FMS in the child and youth population include Mitchell and colleagues who examined the relationship between the Functional Movement Screen, core strength, posture and body mass index in school children aged eight to eleven years. This study showed, that based on the test scores, none of the tests were too difficult for children but further research is needed to assess children's functional fitness (Mitchell, et al. 2015). Abraham, et al. 2015, conducted a study that looked at normative values of the Functional Movement Screen in adolescent school aged boys and girls aged between ten and seventeen years. That study did not separate the children into different stages of maturation but had a large population of one thousand and five participants and provided normative values for participants over wide ranges of maturation. Anderson, et al. 2015, looked at FMS differences between male and female secondary school athletes examining sixty secondary school athletes but again the study did not separate the children into different stages of maturation. The only study evaluate the FMS at different stages of maturation was conducted by Paszkewicz in 2013, in which sixty six adolescent athletes, both male and female, aged between eight and fourteen were assessed using the FMS and separated into Prepubertal, Pubertal and Post Pubertal groups. They were selected using the modified pubertal maturation observational scale (Paszkewiz et al., 2013). They found a non-linear development pattern in FMS scores in the 37 male subjects (Prepubescent - 14.06 mean, Pubertal - 13.73 mean and Postpubescent – 16.22 mean).

Studies have utilized screening statistics to establish the cut off score of <= 14 as being appropriate to identify individuals who have greater risk for sustaining an injury (Kiesel, et al. 2007; O'Connor, et al. 2011). Risk ratio in these studies has ranged between 2.3-8.3 in professional American football players, soldiers in basic training and firefighters in training, all utilizing the cut point of < or = 14 (Kiesel et al., 2007, O'Conner et al., 2011). A study by Chorba et al., (2010), supported these findings in college athletes however the positive likelihood ratio was not significant (Chorba, et al. 2010). Additionally, a study that validated the presence of asymmetry on the FMS and associated it with an elevated risk for injury in professional American football players (Kiesel, et al. in review). Future research is needed with large sample sizes in other population groups to understand what factors on a movement screen are relevant to identify individuals with an elevated risk of injury. Bardenett, et al. (2015), examined the FMS as a predictor of injury in high school athletes and found it to be useful for recognizing deficiency in certain movements; however this data suggests that the FMS should not be used for overall prediction of injury in high school athlete's through-out the course of a season. A systematic review and meta-analysis was recently completed and concluded that there is not sufficient support for injury predictive validity in the FMS (Dorrel, et al. 2015). For the purposes of the current study it was decided not to use the FMS as an injury predictor but as a screening tool to assess movement pattern. While establishing the validity of the screen for assessing movement is beneficial it would have little clinical relevance if performance on the FMS was not modifiable. Studies have reported that scores on the Functional Movement Screen can be improved with implementation of a 6 week training program (Goss, et al. 2009; Cowen, et al. 2010 and Kiesel, et al. 2010). Improvements in the composite FMS score ranged from 2.5-3.3 on average and this is relevant to the current study as one of the aims is to assess normative values of functional competence and help guide the physical development programme for Elite Youth football players.

An additional point of interest from the Dorrel, et al. (2015) study was that no matter what subtest of the FMS was focused on, for the corrective exercise progression, the largest improvements in scores were observed in the core stability tests. Frost, et al. (2012) has reported that FMS scores did not change across a twelve week programme in firefighters in comparison to a control group. Differences in the result may be related to nuances in the interventions, and that considered it is likely that not all corrective exercise programming or strength and conditioning programming may results in a change in FMS scores as it may be related to the expertise of the coach.

Research on various models of retraining has suggested that individualized attention to form and correct movement in youth basketball players can lead to greater improvements in the FMS across a standardized training period (Klusemann, et al. 2011). However the area remains an important factor in relation to physical performance, and Chapman, et al. (2014) concluded that FMS scores and the determination of bilateral asymmetry in elite track and field athletes are associated with the magnitude of longitudinal performance changes. The raw scores on the deep-squat movement of the FMS were also associated with the magnitude of longitudinal performance changes, and this is an important factor when looking at maturity levels and the progression of training over time. The data scores outlined by Chapman extend the knowledge of relationships between FMS scores, bilateral asymmetry and injury occurrence to include a measure of objective competitive performance data. While further research on longitudinal performance changes as they relate to FMS scores and asymmetry presence needs to be conducted, it is likely that this simple screening tool for functional movement deficits may provide athletes and coaches with reliable information that can influence both sport-specific and functional movement training and with a direct impact on athletic performance markers.

More specifically in relation to elite youth football players, Weavers and Duncan, (2015) investigated the relationship between functional movement screens scores, maximal strength, vertical jump and sprint times in 16 youth players from a professional academy. They concluded that there was a significant correlation ($r = 0.67$, $P = 0.013$) between FMS scores and maximal strength, but no significant correlation between FMS and both vertical jump and sprint times. They suggested that although there was a relationship between FMS and strength the assessment did not translate in the performance measures of speed and power. This highlighted the need for further research to examine if stronger athletes have improved functional movement or whether those with better functional movement can progress in strength training and other performance areas.

Results from a study by Nightingale, et al. (2015) on 37 male ice hockey players from a national youth training programme, found that maturation offset was significantly correlated with upper and lower body strength but found no significant correlations between maturation offset and speed and power. He highlighted that the lack of significant correlations with speed and power could be explained due to energy metabolism in youths and intermuscular coordination issues.

The Functional Movement Screen is a reliable tool that could be used to identify deficiency in certain movements (Bardenett, et al. 2015). It has been noted that improvements in the composite FMS score can occur through some movement related training programs (Dorrel, et al. 2015). However despite the growing interest in the use of functional movement screen within athletic development programmes no studies looked at normative values for three stages of maturation and the relationship between maturation, FMS, speed and power.

2.3 Power

The countermovement jump is a common test for measuring jump performance which requires lower loading ground reaction forces and lower loading rates in the lower extremities (Wu, Chang, Liu, & Wang, 2010). The hands-on-waist countermovement jump (CMJ) is one variation of the countermovement jump protocols. It reduces the lower extremity stretch shortening cycle (SSC) capability contributed by arm swing, thereby being more reflective of leg performance (Hara, Shibayama, Takeshita, Hay, & Fukashiro, 2008). Equipment using electronic mat system has been developed to acquire jump height values from CMJ performance (Bosco, Luthanen, & Komi, 1983). Contact mat system estimates lower body performance from flight time which is initiated from lift off and deactivated from landing. Studies establishing the reliability of contact mat technologies are presented. For example, Miller and Callister (2009) tested the reliability of CMJ on male and female participants using a contact platform and revealed intra-class correlation coefficients (ICC) of 0.98.

According to Watkins (2009), the elasticity of muscle and tendons has been demonstrated to affect performance in stretch shortening cycle (SSC) movements and its importance in sprinting and jumping has been well documented. The SSC is typically characterised by an eccentric (lengthening) muscle action, followed by a concentric (shortening) muscular contraction. Using a stretch immediately prior to a concentric contraction has been shown to increase the concentric phase resulting in augmented (increased) force production, power output and a shift in the force-velocity curve to the right as seen in figure 1 below, which demonstrates a basic example of the Force-Velocity relationship. (Force is displayed on the y-axis and velocity on the x-axis).

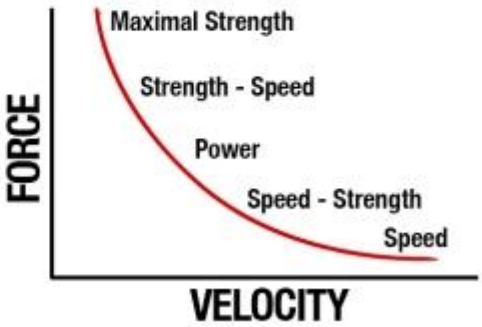


Figure 1: *A basic example of the F -V relationship*

The increased power output evident after a countermovement jump (CMJ) can be explained by the time required to build up force, storage and re-use of elastic energy, potentiation of the contractile elements and reflex contributions. Players can perform various forms of strength training to improve their ability to exert power using the SSC mechanism, and a sound understanding of the mechanisms and assessment methods of the SSC can influence training programme design and moreover sub sequentially enhance performance.

As documented, soccer is an intermittent high-intensity activity during which short bouts of very intense activity are interspersed with lower intensity movement (Stolen et al. 2005). Explosive vertical jumping has been deemed to be important to optimal performance in soccer and also considered important in testing for fitness development (Stolen et al. 2005). The countermovement jump has been shown to be related to competitive success in elite-standard club teams in soccer (Arnason, et al. 2004). Jump testing demonstrates good practicality, feasibility, reliability and sensitivity in tracking changes during the competitive season (Stolen et al. 2005), and they have a high relevance to the game as regards the logical validity has similarity with heading the ball. Jump assessment can take the form of countermovement jumps with test performance comparison used to assess lower limb stretch-shortening efficiency (McGuigan, et al. 2006). Recently the interest in performance potentiation, with regard to stretch shortening movements has grown in sport performance analysis (Bobbert & Casius, 2005). However despite the interest in training monitoring and prescription of assessing stretch shortening cycle efficiency in soccer, no systematic study was available that examined different stages of biological maturation.

A study by Inness et al. (2009), found correlations increased for CMJ height and peak power, and drop jump (DJ) height and peak power as sprint distances increased. This high correlation between CMJ and DJ parameters is possibly due to the foot contact during the CMJ and DJ which is more comparable to top speed sprinting than the squat jump. This study highlights the underpinning relationship between speed and power which may need to consider maturity levels as a factor in this relationship. Based on performance testing, greater emphasis may be placed on short or long sprint performance depending on individual player abilities. Assessment of the CMJ at different stages of maturation will help inform the player and stage specific design of physical development programmes.

2.4 Speed

Speed is widely accepted as an important attribute in football. The relationship between age, maturity, body size and maximal sprint speed in boys with a mean age of 13.0, (SD = 1.3) was examined using the Khamis-Roche method (Khamis & Roche, 1994) as a tool to assess maturity (Meyers, et al. 2015). Step length was also measured as a possible influential factor on sprint speed. Results indicated that leg length, maturity and body mass were the best predictors of sprint speed although it was noted that body mass can negate sprint speed. Myers concluded that the design of training programmes was a critical factor to enable boys to accommodate the anthropometrical changes, especially body mass, during the growth and maturation process. It is important to understand the complexity of what is meant by the term 'speed' which has different meanings in the context of different activities and sports. For example, reaction and the initial rate of force development will determine speed for the combat sport athlete. Reaction and acceleration and the ability to reproduce these speed qualities are important for participants in games such as basketball, tennis and soccer. Reaction, acceleration and full-flight sprinting will be important for the 100m sprinter (Jeffreys, 2009). In some activities, such as combat sports, racquet games and throwing activities, limb speed is important. Speed in these activities is related to the skilful execution of the event's technique and is also limited by neuromuscular factors and limb size. Furthermore, some field game players demonstrate exceptional anticipatory abilities which give the appearance of a fast response. Several types of speed are summarised in Figure 2.

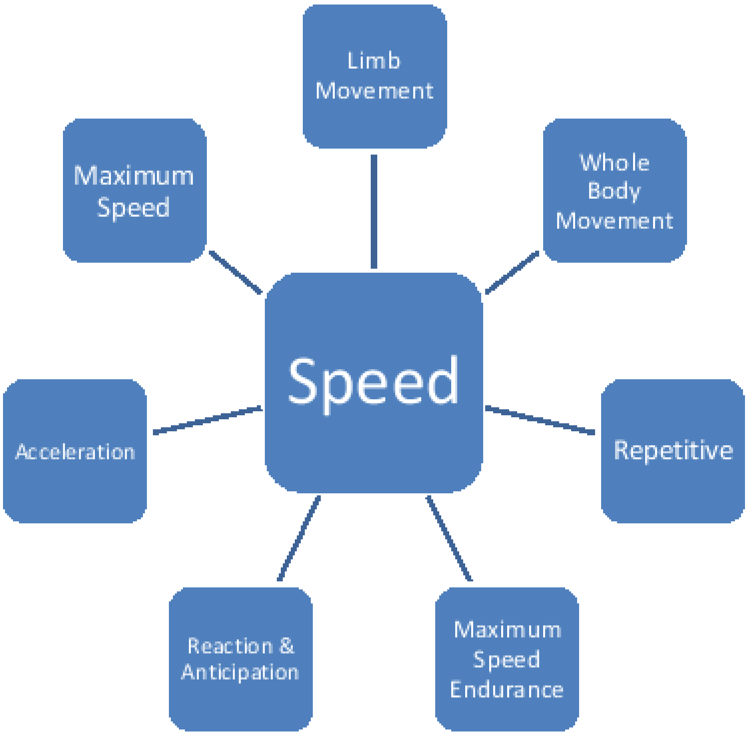


Figure 2: *Most sports demand the expression of at least one type of speed (Dintiman & Ward 2011)*

In general, training procedures should seek to improve reaction and acceleration in virtually all explosive sports (Jeffreys 2009). For athletes, who require sprinting speed (e.g. in running, games,) additional development of maximum speed and the capacity to continue to maintain it, is important. Soccer consists of different categories of motion including acceleration, maximal speed, and agility (Reilly T, Bangsbo J, and Franks 2000). Athletes who participate in field sports are thought to have dissimilar running mechanics than sprint athletes. Little and Williams (2007), conducted a study to determine the extent to which top speed, acceleration, and agility are distinct physical attributes in professional soccer players. Acceleration and maximum speed were the most significantly correlated tests (r = 0.623), with acceleration and agility being the least significantly correlated test (r = 0.346). They concluded that acceleration and maximum speed were the most significantly correlated tests (r = 0.623), with acceleration and agility being the least significantly correlated test (r = 0.346), concluding that agility, power, acceleration, and maximum speed are independent of one another as different physiological and biomechanical factors contribute to an athlete performing well on the various tests of these capacities.

It was established by Lawrence (2015), that peak speed demonstrated a strong association with maturity levels ($r = 0.55$, $P < 0.05$) in elite youth football players aged 13-17 years, with post PHV being significantly faster than pre PHV and circa PHV. Maturity and high intensity effort produced a negative association ($r = -0.40$, P, 0.05) where pre PHV attained significantly more efforts than post PHV. He suggested that the higher running intensity levels of the less mature player increase the injury risk for those players and also that further research was needed to examine the possibility that the lower speeds of the pre PHV group are compensated for by higher effort and then post PHV players, or if tactical astuteness was the key variable.

Functional competency also plays an important role in the player's acceleration and speed (Clark, 2004), and the appropriate length tension relationship is crucial in the sprinting action. The primary actions in sprinting are extension of the hips and legs and plantar flexion of the ankles (Jeffreys 2009). Probably the greatest action contributing to speed is hip extension. Powerful hip extensors are vital in driving the thigh down and back as the athlete is propelled forward. The major muscle groups involved are the gluteal and hamstring muscles. These muscles need to be trained hard and specific to their function in sprinting. Commonly, the hamstrings are trained using the Romanian dead lift and other similar posterior chain exercises (Stone, et al. 2007). The hamstrings are forcefully used in hip extension and need to be trained for this purpose. Exercises like walking lunges, gluteal / hamstring raises, back extensions and straight leg deadlifts strengthen the hamstrings. These exercises develop the hamstrings in a manner specific to sprinting.

The gluteal muscles are powerful hip extensors and many of the exercises used to develop the hamstrings also work the gluteal muscles. In addition, parallel back squats, power cleans, and power snatches, single leg squats, weighted step-ups and other similar lifts have proved successful at developing strong, powerful gluteal muscles (Stone, et al. 20007). The knee extensors are used to support the body and to assist in driving it forward. The knee extensors are developed with leg press, standing lunges, back squats and the majority of exercises used to train the gluteal muscles. The muscles used in plantar flexion are those that make up the calf muscle bulk, namely the gastrocnemius and soleus muscles. These muscles give the final push off in the propulsion of the player in running mechanics. To train the calf muscle requires various forms of calf raise exercises, both single and double leg (Stone, et al. 2007).

An investigation by McBride, et al. (1999) provides evidence that resistance based strength training and functional movement competency for athletes should be adapted to meet the demands of their on-field activities according to high force, low velocity (strength); high force, high velocity (strength, power); or low force, high velocity (performance, power) components. This may have implications for developing acceleration in athletes of different maturity levels (Lloyd and Oliver, 2012).

A study by Lockie, et al. (2012), examined the effects of different speed training protocols on sprint acceleration kinematics and muscle strength and power in field sport athletes. A variety of resistance training interventions are used to improve field sport acceleration (e.g., free sprinting, weights, plyometrics, resisted sprinting). The effects these protocols had on acceleration performance and components of sprint technique have not been clearly defined in the literature. Lockie, et al. (2012), assessed 35 male field sports players on 4 common protocols (free sprint training [FST], weight training [WT], plyometric training [PT], and resisted sprint training [RST]) for changes in acceleration kinematics, power, and strength in field sport athletes. After the interventions, paired-sample *t*-tests identified significant ($p \leq 0.05$) within-group changes. All the groups increased the 0- to 5-meter and 0- to 10-meter velocity by 9–10%. All the groups increased step length for all distance intervals. The study concluded, that correctly administered, each training protocol can be effective in improving acceleration. To increase step length and improve acceleration, field sport athletes should develop specific horizontal and reactive power (Jeffreys 2009). By implication there may be an associated need to enhance functional competence in order to softly complete physical development programme stated above to accommodate improved acceleration (Jeffreys 2009).

Sprint distance and high intensity running distance have increased over the seven seasons leading up to the 2012-13 seasons in the English Premier League (Bush, et al. 2014). This highlights the importance of speed and speed development in future professional players. In a study by Burgess, et al. (2006) data was collected by the use of either semiautomatic video analysis systems or global positioning systems. The analysis of this information shows that male outfield players cover 9-12km during a match (Burgess, et al. 2006). High intensity running or sprinting makes up 8-12% of the total distance (Burgess et al 2006). Reported peak sprint velocity values among soccer players are 31-32 km/hr (Rampinini, et al. 2007). Sprint frequencies in the range of 17-81 per game for each player have been reported (Burgess, et al. 2007). Mean sprint duration is between 2 and 4 seconds, and the vast majority of sprint displacements are shorter than 20m (Burgess, et al. 2007). Players perform 8 times as many accelerations as reported sprints per match as the accelerations are not long enough to be cross the high intensity threshold. Consequentially well assessed and developed acceleration sprinting speed can be an advantage in professional soccer. The lack of standardisation of sprints in games and the variability of different games lead to challenges assessing speed in games, due to methodological challenges, equipment costs and availability. As an alternative many coaches perform sprint testing of players in order to explore the physical demands and evaluate the training process. The assessment of sprint ability in youth players at different stages of biological maturation would be beneficial to programme design and the development of talented youth players.

2.5 Summary

No published reports have examined normative values for the functional movement screen scores at different stages of biological maturation in youth football players and investigated if there is a difference in functional competence, countermovement jump and speed between three stages of biological maturity in youth soccer players? The study aims to establish normative values of functional competence, and to assess functional competence, countermovement jump and speed for youth football players at different stages of biological maturation. In doing so the study attempts to establish if there is a difference in functional competence, countermovement jump and speed between three stages of biological maturity in professional academy based youth soccer players? Limited research is available using chronological age and shows a liner improvement with age in speed and power (Gonaus & Muller, 2012, Buchheit et al, 2012 & Amonette et al, 2014). Though there is a substantial lack of research in this area and in particular in relation to elite youth players, there are indications from the literature that substantial additions to the knowledge base on the protocols for developing speed and leg power at different maturity level and in relation to their functional competence and movement pattern ability, would enhance the development of elite youth players.

Chapter 3

Methods

3.1 Purpose of Study

The purpose of the study was to establish normative values for functional competence, speed and lower body power for Elite Youths soccer players at different stages of biological maturity and determine their relationship with the different stages of maturity. The aim is to inform the strength and conditioning content of programmes at different stages of development in soccer playing youths. A key study by Lawrence (2015), found that peak speed demonstrated a strong association with maturity levels in elite youth football players aged 13-17 years, with post PHV being significantly faster than pre PHV and circa PHV. Maturity and high intensity effort produced a negative association. This study formed a platform for more extensive research to include power and functional competence as well as power across different maturity levels. Currently no normative values for functional competence, speed and lower body power at different stages of biological maturity in Elite Youth soccer players are available.

3.2 Research Questions

1. Is it possible to provide valid estimates of three different biological maturity stages using the Khamis-Roche method, (Khamis & Roche 1994) in a youth soccer population?

2. What are the normative values at different stages of biological maturity for functional competence, countermovement jump and speed?

3. Is there a relationship between functional competence, countermovement jump and speed between three stages of biological maturity in youth soccer players?

3.3 Null Hypothesis

1. There was no significant relationship between maturity and speed, CMJ and FMS at three different biological maturity stages.

2. There was no significant relationship between speed and power at three different biological maturity stages

3. There was no significant relationship between speed and functional movement at three different biological maturity stages

4. There was no significant relationship between power and functional movement at three different biological maturity stages

3.4 Participants

One hundred and thirty male soccer players (n=130) of mixed ethnicity within an English Premier League club, from 7 different age groups, from under 11 to under 18, with a Mean age of 13years 9.68 months, (SD2 years 9 months) took part in the study. Participants were selected from these age groups to enable the examination of maturity status on functional competence, speed and lower body power in order to establish normative values for child and youth soccer players at different stages of biological maturation. The study also examined if there was a relationship between functional competence, countermovement jump and speed between three stages of biological maturity in youth soccer players. The research aimed to inform the strength and conditioning content of the physical development programme at different stages of biological maturation in soccer playing youth players. The standard training content for the participants in outlined in Appendix 1.

3.5 Procedures

A series of tests were carried on the players to assess biological maturity, functional competence, speed and power. Consent forms were used to get permission was sought from the parents and the club (Appendix 2). Both parents and the club were briefed on the aims and procedures of the study and the confidential nature of the data that would be gathered. The percentage of adult height of one hundred and thirty soccer playing youths aged between 10 and 18 was assessed using the Khamis-Roche method (Khamis & Roche, 1994). This is a reliable non-invasive and practical solution for the measure of biological maturity for matching adolescent athletes (Malina, et al 2007). The subjects were categorised into three groups – Pre pubertal growth spurt, Pubertal Growth Spurt and Post Pubertal growth spurt. Normative values for each category were assessed for functional competence using the Functional Movement Screen, 0 to 10m speed and lower body leg power using the countermovement jump test (CMJ). The Functional Movement Screen (FMS) was used as screening instrument which evaluates selective fundamental movement patterns (Schneiders et al, 2011) which can also be described as evaluating the functional competence of the youth soccer players. As the players are going through acceleration in growth it is important to assess the player's functional competence as well and speed and power (Lloyd et al 2014).

3.6 Biological Maturity Assessment

Biological maturity was assessed non-invasively by incorporating measures of body mass (kg), standing height (cm) and parental height (cm) into a regression equation titled the Khamis-Roche Method. The Khamis-Roche method (Khamis & Roche, 1994) was used to predict the mature height from current age, height and weight of the participant and midparent height (average height of both biological parents). The median error bound (median absolute deviation) between actual and predicted mature height at 18 years of age is 2.2cm in males (Khamis & Roche, 1994). Biological parents of the players reported their heights. As adults tend to overestimate height (Epstein, Valoski, Kalarchian & McCurley, 1995), the self-reported height of each parent was adjusted for over estimation using an equation constructed from over 1000 measured and estimated heights of adults (Epstein, et al. 1995).

Estimated biological maturity status was expressed as a z-score, using percentage of predicted adult height attained at the time of measurement. Boys were classified as Pre pubertal growth spurt when they were assessed to be between 89% or less of predicted adult height, during pubertal growth spurt when they were between 89% and 95% of predicted adult height and past pubertal growth spurt when they were past 95% of adult height. Based on the results of the Khamis-Roche method (Khamis & Roche, 1994), the 130 subjects were divided into three groups – Pre pubertal growth spurt group, n= 46, with a mean age of 11 years 6.9 months (SD 9.56 months); Pubertal Growth Spurt group, n=36, with a mean age of 13 years 8 months (SD 8.55 months); and a Post Pubertal growth spurt group. n= 48, with a mean age of 16 years (SD 0.3 months);

	Number	Mean	SD
Pre Pubertal Growth Group	46	11yrs 6.9 months	9.56 months
Pubertal Growth Spurt Group	36	13yrs 8.0 months	8.55 months

Post Pubertal Growth Spurt Group	48	16yrs 0.3 months	11.53 months
Total Group	130	13yrs 9.86 months	2 yrs 9 months
Oldest		17yrs 7 months 22 days	
Youngest		10 years 2 months 6 days	

Table 1: *Number, Mean age, Max age, Min Age and Standard Deviation*

3.7 Testing Protocols

Fitness testing when completed in a professional manner is a valuable tool that helps plan, monitor and evaluate training progress (Hennessy, 2004). However, fitness testing can be misused through poorly selected tests, administered in an unstandardized manner and administered by inexperienced individuals (Hennessy, 2004). The aim of any testing programme is to obtain information which can be used to improve a player's overall match-play performance. Information gained from well-chosen tests can then be used to design optimal individual training programmes and also used to monitor the effectiveness of a specific training programme (Hennessy, 2004). All subjects were tested to examine normative values of functional competence, lower body power and speed (Appendix 3)

3.8 Test Equipment and Order of Testing

Testing was carried out in the football clubs athletic development centres and indoor training pitches (Protocols for all tests in appendix 3). The athletic develop centres have mondo track flooring and the indoor pitches have third generation pitches. The order of performance testing was standardized with exhaustive tests occurring at the end of the testing day and all results were recorded on recording sheets. Parent height and player date of birth was also collected. The order of the testing was;

- Height measurement
- Weight measurement
- Functional Movement Screen
- Counter movement jump test
- 0-10m speed test

For capacity tests the required devices were used:

- body weight – only a digital scales calibrated against a two known weights (one at lower and one at higher end of weight)
- Harpenden Stadiometer
- FMS Kit
- Jump Mat - Optojump-Next
- Speed tests – Brower electronic timing gates

3.9 Pre-Test Condition of Players

It is well appreciated that fatigue can impact on a player's ability to perform (Paul and Nassis, 2015). As fitness testing is a form of performance it is essential that players approach the performance fitness testing occasion in a rested state. There was at least 48 hours between a previous physical training session and the testing. Where players have just recovered from injury or illness this should be noted. A standard warm-up was completed by all participating players. Standard clothing and footwear was established, and players who presented for testing with any signs or symptoms of injury were not included in the study (Paul and Nassis, 2015).

Instructions to Players

Players were clearly instructed how each test was to be performed. This will require a learning phase for those who are new to tests. Instructions for each test were given to the group at the start of the session and before each test.

Motivation

Performance tests by and large require a high degree of concentration and alertness in order to achieve a maximal effort (Paul & Nassis, 2015). It is therefore important and assumed that all players are prepared mentally for the type of test that is to be performed.

To ensure standardisation and to limit circadian fluctuation, a standard warm up was implemented, and tests were completed at the same time of day, in the same order, using the same measurement systems (Hennessy, 2004). All participants would have completed all the testing battery a minimum of once before for familiarity in the early stages of their career therefore they were familiar with the test proceedings. The participants completed the body mass, standing height and functional movement screen (Cook, et al. 2006a & 2006b) prior to the warm up. Participants completed a 10min dynamic warm-up, inclusive of 7min light dynamic mobilisation and activation exercises targeting the main muscle groups of the upper and lower extremities and 3 minutes of multidirectional running gradually building up intensity (Appendix 4). Following the warm up and an opportunity to re familiarise with the tests protocols, all participants completed the battery of tests with the countermovement jump test (Bosco et al. 1983) and the ten meter speed test (Hennessy, 2004). The researcher was an accredited and experienced strength and conditioner and Level two qualified functional movement screen accreditation. Data collection took place during club training time and the total time to complete the testing battery was approximately two hours for each age group. Participants were asked to not complete any physical activity for forty eight hours before testing and were asked to refrain from eating two hours before testing.

Functional movement screen

Participants were screened using the functional movement screen protocol that comprised of the following seven movement patterns: deep overhead squat, in-line lunge, hurdle step, active straight leg raise, trunk stability push up, shoulder mobility and rotary stability. Participants were given three trials of each movement, with each trial being scored by the author in real time on a 4 point scale (Table 2) according to the functional movement screen rating manual and previous research (Cook et al 2006a). As per the functional movement screen testing guidelines (Cook et al 2006a), the highest score was recorded and used for subsequent analysis, and in the instance where the movement pattern was completed on left and right sides (i.e. in-line lunge, active straight leg raise, hurdle step, shoulder mobility and rotary stability), the lower of the two scores was recorded.

Score	Criteria
3	Participant is able to perform the movement correctly without compensation
2	Participant is able to complete the movement but performs with compensation (s)
1	Participant fails to complete the movement or is unable to assume the

	position to perform the movement
0	Participant has pain anywhere in the body at any time during the test

Table 2: *Scoring criteria for the functional movement screen protocol (Cooke et al., 2006a)*

Participants also completed additional movement dysfunction clearing tests as recommended by Cook (2006) to identify the presence of pain following functional movement screen guidelines (active impingement, trunk flexion, and trunk extension tests). None of the participants reported pain during any of the clearing tests.

Countermovement Jump Test

Lower body power was assessed by using a portable optical timing system (Optojump Next; Microgate, Bolzano, Italy). The Optojump-Next system consists of 2 bars (i.e., transmitting and receiving bars, 1m) that are equipped with 33 optical LED's. The LED's fitted in the transmitting bar continuously communicate with the corresponding set in the receiving bar. The leds are positioned at 0.3 cm from the ground level and at 3.125-cm interval. Any break of the beam switched on and off a handheld digital chronometer, used to calculate flight times (i.e. 1 x 1000.s -1 manufacturer-declared accuracy) (Castagna & Castellini, 2013).

The time interval from take-off to the maximum height of the jump equals the time interval from the maximum height of the jump to landing, the height of the jump is calculated as follows:

$H = 0.5\ g\ t^2$,

Where H is the height of the jump, g is the acceleration of gravity, and t is half of the flight time. Players performed a CMJ according to the protocol described by (Bosco, et al. 1983). Before testing and the warm up the players complete a self-administered submaximal CMJ's (3 repetitions) as practice. Subjects were asked to keep their hands on their hips to prevent any influence of arm movements on the CMJ and to avoid undue jump techniques that may have affected flight time accuracy, subjects were required to fully extend lower limbs at take-off and to keep as stiff as possible their legs at landing. To facilitate players in correct movement they were asked to preform submaximal stiff-leg bouncing at landing from the CMJ (Bosco, et al. 1983 & Hennessy 2004).

Only CMJ's that satisfied the protocols were retained for examination. Each subject performed 3 maximal CMJ's. The players went in alphabetical order, with approximately 30sec recovery in between. Players were asked to jump as high and as explosively as possible, and the highest jump was used for analysis. Reliability of the CMJ has been shown in previous studies to be very high (intraclass correlation coefficient 0.94-0.97) (Chaouachi, et al. 2009, 2010) Chtara, et al. 2008). Validity of the vertical jump device was reported elsewhere (Castagna & Castellini, 2013).

Speed Test

The purpose is to assess speed from a stationary start. The distances selected represent the distance most frequently covered during a game at maximum pace. Typically, they vary between 5-20 metres (Burgess, et al. 2006). This means that acceleration is a key 'speed' component required in the game of Soccer. The sprint test was completed on an indoor third generation pitch. The distance was measured twice before the test was completed. The players sprinting ability was measured by maximal 10m straight line sprint. Infrared timing gates with 0.01s accuracy (Brower Timing Systems, Utah, USA) were placed at 95cm from ground level to light at 0m and 10m. The gates are placed 20m either side of a 1m running lane. Players started in a standing position 0.7m behind the first timing gate. Cones are placed 5m past the 10m mark and places are instructed to sprint pass the cones. The players completed a standardised warm up which included gradual build up sprints. The author ensured he was within 5m of the start position to ensure compliance. No sway or countermovement is allowed and the player starts of his own volition. This start position was practised prior to the testing day for all players. The players completed three maximal sprints with a minimum of three minutes between each sprint.

3.10 Data Analysis

The means and standard deviations for each test at different stages of maturation are provided. The Pearson product-moment correlation coefficient was used to measure of the strength of the linear association between variables and was denoted by *r*. A Pearson product-moment correlation attempts to draw a line of best fit through the data of two variables, and the

Pearson correlation coefficient, r, indicated how far away all these data points are to this line of best fit. This was used to examine the relationship between the variables of maturity, 10m Speed, CMJ and FMS. The stronger the association of the two variables, the closer the Pearson correlation coefficient, *r*, will be to either +1 or -1 depending on whether the relationship is positive or negative, respectively.

3.11 Ethical Considerations

The project received ethical approval from WIT ethics committee, and both participant consent and parental permission were obtained prior to testing along with permission from the host academy of the football club involved in the study.

3.12 Limitations

The limitations of the study included;

- The range of tests which could be carried out on the subjects was limited to FMS, speed and power. Maximal strength, flexibility, body composition, speed endurance and other tests were completed but outside the scope of this study.
- Injury to players at the time of testing reduced the number of subjects that could be tested.
- The study was limited to one academy.
- The participants are of mixed ethnicity and the maturation assessment method was assed using Caucasians.
- The number of subjects for each maturity stage was limited by the subject's current biological maturity at the time of the testing.
- It is only an assessment of the players at one moment in time and not a longitudinal study following the player's development over a number of years.
- All the players were receiving strength and conditioning support at the time of the assessment so it was not possible to see any assessment results of players who were not receiving strength and conditioning support.

Chapter 4

Results

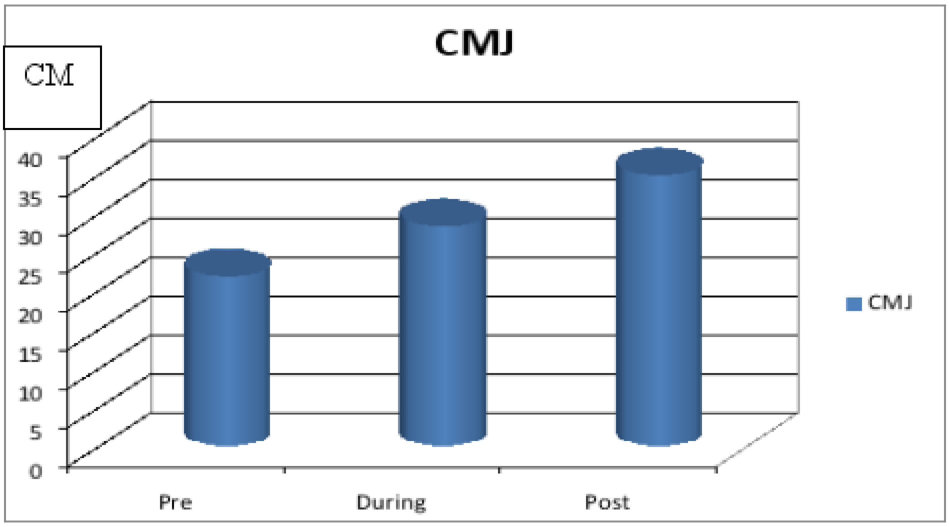
4.1. Results

The means and standard deviations for each test at different stages of maturation are provided in table 3. The results below are from the testing of 130 elite academy football players aged 10 to 18 years of age. The areas tested are counter movement jump (cm), speed over 10m (sec) and the total score of the functional movement screen. The 130 players where then divided into three groups. Pre pubertal Growth Spurt: n=46 subjects with the mean age of 11 years 9.6 months. - Pubertal Growth Spurt: n=36 subjects with the mean age of 13 years 8 months –Post Pubertal Growth Spurt group: n=48 subjects with the mean age of 13 years 9.8 months.

	CMJ	Speed	FMS
Pre Pubertal Growth Spurt	22.02 +-4.32	1.99 +-.118	15.78
Pubertal Growth Spurt	28.48 +-4.82	1.83 +-.115	15.58
Post Pubertal Growth Spurt	35.07 +-4.90	1.72 +-.064	16.89

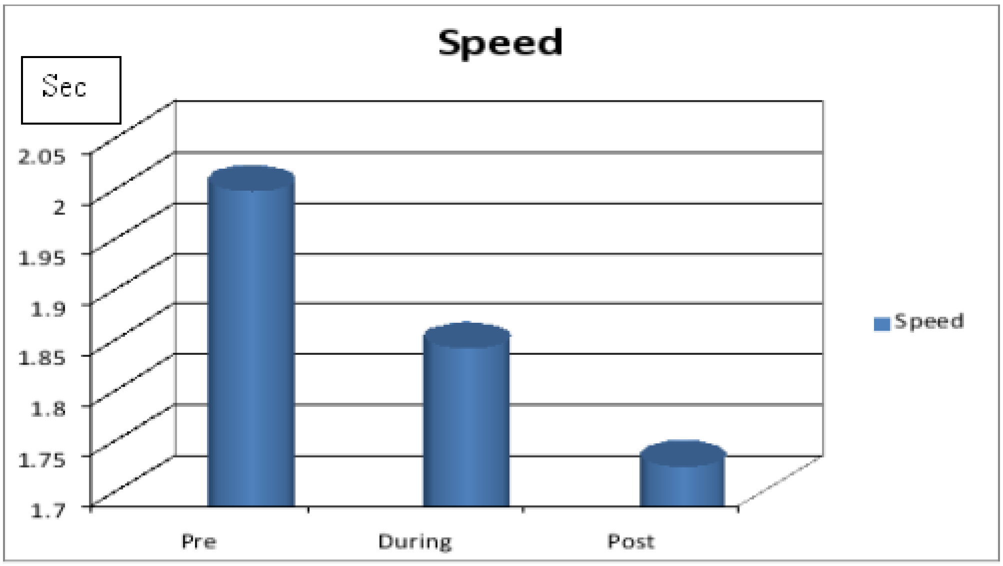
Table 3: *The means and standard deviations for each test result at different stages of maturation*

In the below graph 1 the mean of the countermovement jump (cm) scores show a gradual increase in power from stage to stage. This increase happens linearly from pre pubertal growth spurt to during pubertal growth spurt and to post pubertal growth spurt. This is consistent with other literature that divided players into similar groups using chronological age (Gonaus & Muller, 2012, Buchheit et al, 2012 & Amonette et al, 2014).



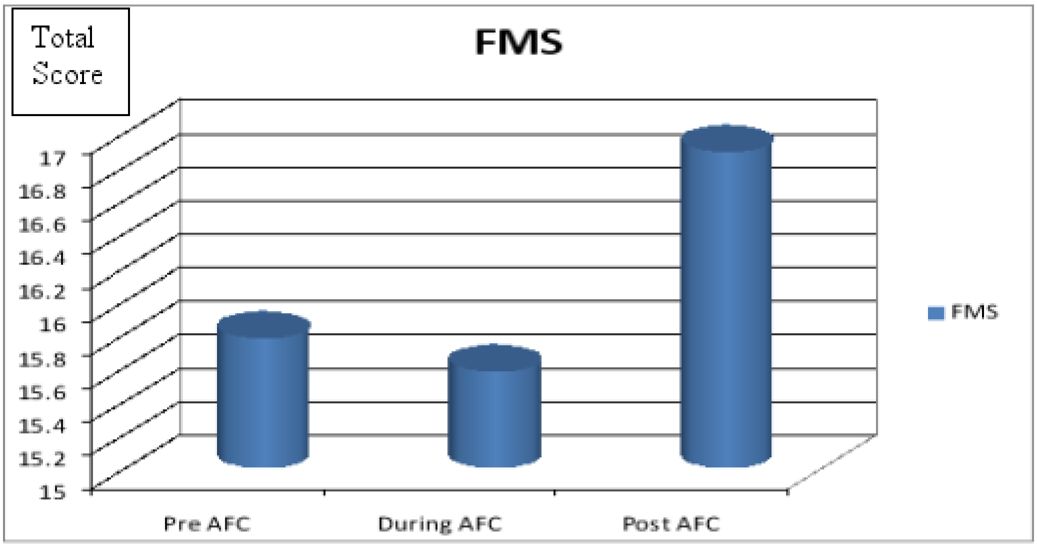
Graphs 1: *Mean Countermovement Jump Mean Height (cm)*

The same trend can be seen in 0 to 10m speed time. The mean time of the 10m sprint show's a gradual increase in speed from stage to stage. This increase happens linearly from pre pubertal growth spurt to during pubertal growth spurt and to post pubertal growth spurt as can be seen in graph 2 below. This is consistent with other literature that divided players into similar groups using chronological age (Gonaus & Muller, 2012, Buchheit et al, 2012 & Amonette et al, 2014).



Graphs 2: *Mean 0 to 10m Speed Time (seconds)*

The trend is slightly different in graph 3 which shows the Functional Movement Screen total score. There is not a gradual increase from pre pubertal growth spurt to during pubertal growth spurt and then an increase from during pubertal growth spurt to post pubertal growth spurt.



Graphs 3: *Total Functional Movement Screen Score*

4.2 Correlations

The mean and standard deviations for subjects are displayed in Table 4 below.

Descriptive Statistics for all groups combined

	Mean	Std. Deviation	N
Maturity	2.02	.853	130
CMJ	28.6338	7.25316	130
TenM	1.8506	.15375	130
FMS	16.1385	2.13409	130

The Pearson product-moment correlation coefficient is a measure of the strength of a linear association between two variables and is denoted by *r*. Basically, a Pearson product-moment correlation attempts to draw a line of best fit through the data of two variables, and the Pearson correlation coefficient, r, indicates how far away all these data points are to this line of best fit. This was used to examine the relationship between the variables of maturity, 10m Speed, CMJ and FMS. The stronger the association of the two variables, the closer the Pearson correlation coefficient, *r*, will be to either +1 or -1 depending on whether the relationship is positive or negative, respectively.

Correlations for all groups combined

		Maturity	CMJ	TenM	FMS
Maturity	Pearson Correlation	1	.768**	-.757**	.224*

	Sig. (2-tailed)		.000	.000	.010
	N	130	130	130	130
CMJ	Pearson Correlation	.768**	1	-.834**	.401**
	Sig. (2-tailed)	.000		.000	.000
	N	130	130	130	130
TenM	Pearson Correlation	-.757**	-.834**	1	-.324**
	Sig. (2-tailed)	.000	.000		.000
	N	130	130	130	130
FMS	Pearson Correlation	.224*	.401**	-.324**	1
	Sig. (2-tailed)	.010	.000	.000	
	N	130	130	130	130

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 4: *Pearson product - moment correlation coefficient for all groups combined*

Table 4 above shows Pearson product-moment correlation coefficient for all groups combined. There were significant relationships between maturity and speed, CMJ and FMS. The most significant relationships were between maturity and speed (r = -.757) and CMJ (r =.768) with a weaker association of (r = .224) for FMS. Therefore the hypothesis (1) that stated that there was no significant relationship between maturity and speed, CMJ and FMS was rejected.

Below table 5 shows the Pearson product-moment correlation coefficient for the Pre Pubertal Growth Spurt group. It looked at correlations between CMJ, FMS and Speed.

Pre Pubertal Growth Spurt Maturity (Level 1)

Correlations[a]

		CMJ	TenM	FMS
CMJ	Pearson Correlation	1	-.706**	.126
	Sig. (2-tailed)		.000	.406
	N	46	46	46
TenM	Pearson Correlation	-.706**	1	-.233
	Sig. (2-tailed)	.000		.119
	N	46	46	46
FMS	Pearson	.126	-.233	1

	Correlation			
	Sig. (2-tailed)	.406	.119	
	N	46	46	46

**. Correlation is significant at the 0.01 level (2-tailed).

a. Maturity = Level 1

Table 5: *Pearson product – moment correlation coefficient for the Pre Pubertal Growth Spurt group*

A significant relationship was found between CMJ and 10m Speed at r = -.706 ($P<0.05$) at the Pre Pubertal Growth Spurt stage. No significant relationship was found between FMS and either CMJ at (r = .126) or 10m Speed (r = -.233) at this maturity level so the hypothesis 3 and 4 that stated there would be no significant relationship between speed and functional movement at three different biological maturity stages and there would be no significant relationship between power and functional movement at three different biological maturity stages are accepted. The hypothesis (2) that stated that there was no significant relationship between speed and power at three different biological maturity stages is rejected for Pre Pubertal Growth Spurt.

Below table 6 shows the Pearson product-moment correlation coefficient for the During Pubertal Growth Spurt group. It examined correlations between CMJ, FMS and Speed.

During Pubertal Growth Spurt Maturity (Level 2)

Correlations[a]

		CMJ	TenM	FMS
CMJ	Pearson Correlation	1	-.587**	.465**
	Sig. (2-tailed)		.000	.004
	N	36	36	36
TenM	Pearson Correlation	-.587**	1	-.264
	Sig. (2-tailed)	.000		.120
	N	36	36	36
FMS	Pearson Correlation	.465**	-.264	1
	Sig. (2-tailed)	.004	.120	
	N	36	36	36

**. Correlation is significant at the 0.01 level (2-tailed).

a. Maturity = Level 2

***Table 6:** Pearson product – Moment correlation coefficient for the During Pubertal Growth Spurt Group.*

A significant relationship was found between CMJ and 10m Speed at r = -587 (P<0.05) at the During Pubertal Growth Spurt. No significant relationship was found between FMS and 10m Speed (r = -.264) at this maturity level so the hypothesis (3) testing the no relationship between speed and functional movement at During Pubertal Growth Spurt is accepted. However a significant relationship was found between CMJ and FMS at r = .465 (P<0.05) at the maturity level 2 (During Pubertal Growth Spurt). The hypothesis (2) that stated that there was no significant relationship between speed and power at three different biological maturity stages is rejected for maturity level 2. The hypothesis (4) that stated there was no significant relationship between power and functional movement at this level of biological maturity is rejected.

Below table 7 shows the Pearson product-moment correlation coefficient for the Post Pubertal Growth Spurt group. It looked at correlations between CMJ, FMS and Speed.

Post Pubertal Growth Spurt Maturity (Level 3)

Correlations[a]

		CMJ	TenM	FMS
CMJ	Pearson Correlation	1	-.585**	.521**
	Sig. (2-tailed)		.000	.000
	N	48	48	48
TenM	Pearson Correlation	-.585**	1	-.341*
	Sig. (2-tailed)	.000		.018
	N	48	48	48
FMS	Pearson Correlation	.521**	-.341*	1
	Sig. (2-tailed)	.000	.018	
	N	48	48	48

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

a. Maturity = Level 3

Table 7: *Pearson product - moment correlation coefficient for the Post Pubertal growth Spurt group.*

For Post Pubertal Growth Spurt a significant relationship was found between CMJ and 10m Speed at r = -.585 (P<0.05) and therefore the hypothesis (2) that stated that there was no significant relationship between speed and power at this biological maturity stage is rejected. A significant relationship was found between FMS and both CMJ, r = .521 (P<0.05) and speed r = -.341 (P<0.05) so both the hypothesis (3 and 4) stating no relationship between both CMJ and 10m Speed, and functional movement at maturity level 3 were rejected.

Table 8 below gives a summary of the Pearson Correlation results at the three stages. It shows at Pre Pubertal Growth Spurt stage there is a correlation between speed and jump but not speed and FMS or Jump and FMS. During the Pubertal Growth Spurt there again was a correlation with speed and jump and again no correlation with speed and FMS but there was a correlation with FMS and Jump. There was a correlation with all three in the final post growth spurt stage.

Table of Correlations				
Maturity Level	Test	CMJ	TenM	FMS
Pre Growth Spurt	CMJ Pearson Correlation	1	-.706**	.126
Pre Growth Spurt	TenM Pearson Correlation	-.706**	1	-.233
Pre Growth Spurt	FMS Pearson Correlation	.126	-.233	1
During Growth Spurt	CMJ Pearson Correlation	1	-.587**	.465**
During Growth Spurt	TenM Pearson Correlation	-.587**	1	-.264
During Growth Spurt	FMS Pearson Correlation	.465**	-.264	1
Post Growth Spurt	CMJ Pearson Correlation	1	-.585**	.521**
Post Growth Spurt	TenM Pearson Correlation	-.585**	1	-.341
Post Growth Spurt	FMS Pearson Correlation	.521**	-.341	1
**. Correlation is significant at the 0.01 level (2-tailed).				
*. Correlation is significant at the 0.05 level (2-tailed).				

Table 8: *Pearson Correlation results at the three stages of maturity*

Means, Standard Deviations and the Range of FMS, Power and Speed				
Group	**Subject No.**	**CMJ Mean**	**Standard**	**Max & Min**

			Deviation	
Pre Pubertal Growth Group	46	22.02cm	+/- 4.32	33.1cm & 13.6cm
Pubertal Growth Spurt Group	36	28.48cm	+/- 4.82	38.9cm & 18.3cm
Post Pubertal Growth Spurt Group	48	35.07cm	+/- 4.9	47.7cm & 27.2cm
Total Group	130	28.63cm	+/- 7.25	47.7cm & 13.6cm
	Subject No.	**10m Speed Mean**	**Standard Deviation**	**Max & Min**
Pre Pubertal Growth Group	46	1.99sec	+/- 0.11	2.33sec & 1.79sec
Pubertal Growth Spurt Group	36	1.83sec	+/- 0.11	2.17sec & 1.63sec
Post Pubertal Growth Spurt Group	48	1.72sec	+/- 0.06	1.92sec & 1.62sec
Total Group	130	1.85sec	+/- 0.15	2.33sec & 1.62sec
	Subject No.	**FMS Mean**	**Standard Deviation**	**Max & Min**
Pre Pubertal Growth Group	46	15.78	+/- 2.10	19 & 11
Pubertal Growth Spurt Group	36	15.58	+/- 2.18	20 & 11
Post Pubertal Growth Spurt Group	48	16.89	+/- 1.93	20 & 12
Total Group	130	16.13	+/- 2.13	20 & 11

***Table 9**:* Means, Standard deviations and the Range of FMS, Power and Speed.

Chapter 5

Discussion

5. Discussion

The aims of this study were to assess normative values of functional competence (FMS score), countermovement jump (cm) and 0-10m speed (sec) for Elite Youth football players at different stages of biological maturation (Pre-During-Post Pubertal Growth Spurt). The study also investigated whether there was a difference in functional competence, countermovement jump and speed between three stages of biological maturity in Elite Youth soccer players.

An examination of the results in speed and power over the three stages of biological maturation indicated a linear improvement in countermovement jump height (cm) and 0 to 10 meter speed (sec). Other studies have looked at power and speed at similar stages of development however using chronological age rather than biological age to differentiate the three groups thus confounding results (Gonaus & Muller, 2012, Buchheit et al. 2012 & Amonette et al, 2014). The studies using chronological age show a similar linear improvement as the players got older. The same can be shown in speed but again the authors used chronological rather than biological age to differentiate the groups which could bias results (Gonaus & Muller, 2012, Buchheit et al. 2012 & Amonette et al. 2014). The results of these studies could be accounted for due to training stimulus and or growth and development. When match play running outputs at different stages of biological maturation were assessed by Lawrence, (2015) it showed similar linear increases thus supporting the findings in this authors research. This however cannot be used as reliable repeatable fitness testing as match conditions vary from match to match, but it remains of value to consider match output of players and it is a useful tool to compare with fitness testing results. It is important that speed and power are assessed relative to maturation as inter-individual differences exist in the magnitude, onset and rate of change of various biological components as a result of maturational processes (Malina et al. 2014). There was no such linear increase in the FMS scores in the three stages of biological maturation. The mean score decreased slightly from pre to during growth spurt followed by an increase after the growth spurt. There is limited research on this area apart from one study using observational maturation by (Paszkewiz et al 2013). The Modified Pubertal Maturation Observational Tool (a self-assessment questionannaire) was employed in this study, which consisted of children aged up to 14 however a similar trend of a non-linear development pattern was found with the FMS mean scores in that population when compared to the results of this study. Paszkewiz et al (2013) showed there was a slight decrease (0.33 score) in the mean FMS score from Pre Pubertal Growth Spurt compared to During Pubertal Growth Spurt. There was an increase in the FMS (2.49 score) Post the Pubertal Growth Spurt but this study only used children up to 14 therefore there were limited numbers in that group. The study also used boys and girls making it difficult to compare to this authors results.

Abraham and colleagues (2015) looked at normative values for adolescents but did not categorise them into chronological groups or biological maturation groups just a total population group across all stages. In the current study, the results of the Pre Pubertal Growth Spurt group show a significant correlation ($r = -.706$) between Countermovement jump and the 0 to 10m sprint time. There was no correlation ($r = .126$) between the Countermovement jump and the FMS score or the 0 to 10m speed time and the FMS score ($r = -.233$). It is this author’s opinion that speed and power show a correlation due to an increase in size and strength in the developing players and this increase in size may be the cause for a non-liner effect on the FMS scores thus of limited correlation. An examination of the Pubertal Growth Spurt group the Countermovement jump and 0 to 10m Speed time show a correlation ($r = -.587$). Countermovement jump and the FMS are correlated ($r = .465$) but 0 to 10m speed time and the FMS are not correlated (r = -.233). It is the opinion of the author that with maturation there is an associated increase in size and strength thus resulting in linear positive development for speed and power. The FMS scores could be affected by the increase in size of the player resulting in non-linear development and weak or no correlation with power and speed.

The Post Pubertal Growth Spurt group results show a correlation between Countermovement jump and both 0 to 10m speed time (r = -.585) and the FMS score (r = -.521). The 0 to 10m speed time is correlated to both FMS score (r = -.341) and countermovement jump (r = -.585). Finally the FMS score is correlated to countermovement jump (r = .521) and the 0 to 10m speed time (r = -341). It is this author's opinion that as the player's growth slows down and the player gets used to his increased size and strength the FMS score has a more linear improvement and thus is correlated to speed and power.

From this data it seems that the functional competence and movement pattern ability follows a different developmental pattern compared to the developmental pattern of speed and power which shows a linear progression as opposed to the FMS scores that are non-linear. As stated previously this is supported by Paszkewiz (2013) though in a different population and using different methods to assess maturation. We can attribute this non-linear pattern to the increase in stature during the pubertal growth spurt which can lead to a concept termed "adolescent awkwardness" (Philippaerts et al., 2006). Adolescent awkwardness may be reflected in the lower movement pattern scores as shown by the FMS scores in the During Pubertal Growth Spurt group. It is accepted that at the onset of puberty a rapid increase in the rate of growth and increase in muscular strength are experienced (Parker et al., 1990). This can explain the linear increase in speed and power for the population in the study however this study also shows the developmental pattern of functional competence and movement pattern ability does not follow the same pattern as speed and power. Adolescent awkwardness may be reflected in the lower movement pattern scores as shown by the reduction in FMS scores in the During Pubertal Growth Spurt group.

Chapman et al (2014) concluded that FMS scores in elite track and field athletes are associated with the magnitude of longitudinal performance changes. From this study it can be inferred that the higher the FMS score a player has the greater the chance the athlete has of positive longitudinal performance change in areas such as speed and power. Chapman studied an adult population however, and it would be recommended that future research needs to be completed with the child and youth athlete. As the FMS score does not have the same developmental pattern as speed and power during the pubertal growth spurt it could be suggested that greater emphasis on training this area during that period could create greater potential to improve speed and power longitudinally and be of significant benefit for youth soccer players, as speed and power are important determinants of superior performance (Reilly T, Bangsbo J, and Franks, 2000). The other benefit of putting greater emphasis on improving functional competence and movement patterns during the pubertal growth spurt that could be linked to the Chapman study is that the player will be able to progress safely to more advanced exercises that can assist performance and development (Cook et al, 2010). This follows a good competency based approach to athletically development players that are recommended by many associations for child and youth players (Faigenbaum et al. 2009 & Lloyd et al. 2012).

When current models and frameworks for developing youth athletes over a long period are investigated, the two models that are most widely recognised are The Long Term Athlete Development Model (Balyi & Hamilton, 2004) and The Youth Physical Development Model (Lloyd and Oliver, 2012). In a review of the Long Term Athlete Development Model, Ford, et al. (2011) recommends that it is critical that the Long Term Development Model is seen as a work in progress and the challenge, particularly for paediatric scientists, is to question, test and revise the model. This study attempts to implement this recommendation, by establishing evidence of a non-linear development in functional competency despite observable and measurable changes in performance markers. This can lead coaches to overlook that while there is a linear development in speed and power, other aspects of the players' needs like functional competence need attention. Balyi & Hamiltons (2004) work states that their model of LTAD contains windows of trainability. These windows have been critiqued by Ford et al. (2011) citing a lack of empirical evidence. Balyi & Hamilton (2004) suggest that during the pubertal growth spurt there is a window of trainability in boys for stamina and speed. There is no mention of development of functional competence, movement pattern or mobility during this phase. This study is suggesting that functional competence, movement pattern and or mobility should be included as an important area for development during the pubertal growth spurt phase as it does not follow the same developmental pattern as speed and power and consequently improvements in functional competence area will possibility enhance future performance and development (Chapman, et al. 2014 and Cook, et al. 2010).

The Youth Physical Development Model (Lloyd & Oliver, 2012) is recognised as the most contemporary model available (Faigenbaum, et al. 2013). This model describes more physical qualities such as fundamental movement skills and mobility and stresses the importance of developing these aspects at different stages of maturation. During the pubertal growth spurt Lloyd and Oliver (2012) deemphasise fundamental movement skills and mobility and emphasise agility, speed, power and strength. Based on the findings of this research it is suggested that mobility and fundamental movement skills should be emphasised at the during pubertal growth spurt stage. As suggested functional competence, movement patterns and mobility should be emphasised as important areas for development during the pubertal growth spurt phase. It is important to highlight these areas as they do not follow the same developmental pattern as speed and power.

These findings are supported by the recent International Olympic Committee's consensus statement on youth athletic development (Bergeron et al. 2015), which reiterated the importance of assessment of biological maturity and suggests athletic development frameworks should be holistic in embracing the multidimensional nature of athlete development, and predicated on recognised best practice for each development phase rather than age related prescription based athletic development.

Furthermore the National Athletic Trainers' Association Position Statement on Prevention of Paediatric Overuse Injuries (Valovich McLeod et al. 2011) places a priority on the importance of training programmes focusing on neuromuscular control, balance, coordination, flexibility and strengthening of the lower body for reducing overuse injuries risk among paediatric athletes with a previous injury history. This supports the evidence for emphasise of improvement of functional competence, movement pattern and mobility content during the pubertal growth spurt. The importance of biological maturation assessment and athletic development is also highlighted by Difiori et al. (2014) in the Overuse Injuries and Burnout in Youth Sports: A Position Statement from the American Medical Society for Sports Medicine.

The current study also goes some way to providing normative data in functional competence, speed and lower body power for professional academy based youth football players at different stages of biological maturity as evidenced in table 10. As the population in this study were one hundred and thirty players (n=130) more data is needed using the same testing protocols to provide high quality normative data.

This population receives regular supervised individualised strength and conditioning content and should not be compared to a population without regular supervised strength and conditioning content. The evidence would suggest that a population that does not receive regular strength and conditioning will have a different physical profile (Lloyd et al, 2012) therefore it may be beneficial to complete a similar study with a non-elite population. There would also be benefit in a longitudinal approach in tracking this population through all stages of development with regular assessments and using different interventions to try and improve the fitness characteristics that were assessed thus providing a good overview of what happens to the child and youth player when trained as they mature.

This assessment of Elite Youth football players was only at one particular moment in time and not a longitudinal follow up study following the player's development. However the study has value as there is limited information on this topic and specific population and the scores in all tests represent a level of talent in a professional football academy. All the players were receiving strength and conditioning support at the time of the assessment therefore it was not possible to determine any assessment results for players who did not receive strength and conditioning support.

Another limitation is the range of tests that were carried out on the subjects. Tests were limited to FMS, speed and power. Maximal strength, flexibility, body composition, speed endurance and other tests were completed by the club, as part of fitness testing protocols. These tests were outside the scope of this study. Injury to players at the time of testing reduced the number of subjects that could be tested. The study was limited to one football academy and the number of subjects for each maturity stage was limited by the subject's current biological maturity at the time of the testing.

Chapter 6

Conclusions and Recommendation

6. Conclusions

The aims of this study were to assess normative values of functional competence (FMS score), countermovement jump (cm) and speed (sec) for Youth Elite academy football players at different stages of biological maturation. The study also investigated if there was a difference in functional competence (FMS score), countermovement jump (cm) and speed (sec) between the three stages of biological maturity (Pre, During and Post Pubertal Growth Spurt) in Elite Youth academy football players. There is a paucity of research in this area and in particular in relation to Elite Youth players. The literature suggests the need to improve the knowledge base for developing functional competence, speed and leg power at different maturity levels in order to enhance the athletic development of Elite Youth players.
The results of this study suggest that the functional competence and movement pattern ability as assessed by the FMS scores of Elite academy based youth footballers follows a different developmental pattern compared to the developmental pattern of speed and power. Speed and Power show a linear progression while the FMS does not follow a linear pattern. This could be linked to the increase in stature observed during the pubertal growth spurt which has been conceptually linked to “adolescent awkwardness” (Philippaerts et al. 2006).

Adolescent awkwardness may be reflected by the reduced movement pattern scores as shown by the reduction in the mean FMS scores in During Pubertal Growth Spurt group. It is well known that at the onset of puberty a rapid increase in the rate of growth and increase in muscular strength are experienced (Parker, et al. 1990). This could explain the linear increase in speed and power for this population and the different non-linear developmental pattern of functional competence and movement pattern ability.

Chapman et al (2014) concluded FMS scores in elite track and field athletes are associated with the magnitude of longitudinal performance changes. The conclusion from this study was that the higher the FMS score a player has the greater chance he has of positive longitudinal performance change in areas such as speed and power. As the FMS score does not have the same developmental pattern as speed and power during the pubertal growth spurt it could be suggested that greater emphasis on this area during that period could create greater potential to improve speed and power longitudinally. This will benefit the youth soccer player as speed and power are important determinants of superior performance (Reilly T, Bangsbo J, and Franks, 2000). Another benefit of putting greater emphasis on improving functional competence and movement patterns during the pubertal growth spurt that could be linked to

the Chapman study (2014) is that the player will be able to progress to more advanced exercises that can assist performance and player development (Cook et al, 2010).
On examination of the current models and frameworks for developing youth athletes over a long period the Youth Physical Development Model (Lloyd and Oliver, 2012) does not support the results from this study with regard to the importance of improving functional competence during this phase. This authors study concludes that functional competence should be promoted as an important area for development during the pubertal growth spurt phase thus improvements in that area will possibly enhance future performance and player development (Chapman et al, 2014 and Cook et al, 2010). This is in contrast to Lloyd and Oliver (2012) whom, during the pubertal growth spurt, deemphasise fundamental movement skills and mobility and emphasise agility, speed, power and strength.

In observing the developmental pattern of functional competence in the current study, it is suggested that mobility and fundamental movement skills should be emphasised at the During Pubertal Growth Spurt stage having concluded that functional competence is important during this stage as it does not follow the same developmental pattern as speed and power and thus trained improvements in that area will possibility enhance future performance and player development (Chapman et al, 2014 and Cook et al, 2010). The importance of the players receiving supervision by a qualified strength and conditioning coach would lead to a competency based approach to athletic development, as recommended by many associations for child and youth players (Faigenbaum et al. 2009 & Lloyd et al. 2012).

Recommendations

Below is a list of key recommendations –

- This study should be repeated using larger participant numbers with a male and female elite player population to create normative values of all tests.
- A similar study should be repeated using a non-elite youth male and female population groups.
- Results for non-elite populations should be compared to elite populations, to examine the effects of supervised sport science and medicine.
- A study to examine the movement patterns at different maturity levels as impacted on by specific area's such as ankle mobility and hip mobility could be conducted
- The population in this study and future studies should be followed longitudinally to examine the actual physical changes in players due to biological maturation.
- Interventions to improve functional competence and movement patterns should be investigated to examine the effects on functional competence and movement patterns and other elements of fitness in longitudinally prospective studies.
- Maturation assessment should be a core component of any research into child and youth athletes.
- Maturation should be used to guide programming content for child and youth athletes.
- This study shows the importance of understanding the developmental pattern of functional competence and movement patterns in child and youth athletes. It demonstrates that emphasis should be placed on movement pattern and mobility during the pubertal growth spurt.
- This study would suggest that adaptations should be made to current long term athletic development models and frameworks. Primarily highlighting the importance of improving functional competence and movement patterns during the pubertal growth spurt to enhance gains from training intervention.
- Longitudinal Research should be conducted to see if improved functional competence and movement patterns, during the pubertal growth spurt, would result in greater gains in speed and power post-pubertal growth spurt compared to no intervention.
- Studies are required to examine the implementation of individualised corrective exercise programmes to improve functional competence and regular athletic development of Elite Academy Football Players.
- Investigations should also consider the effect of improved functional competence and movement patterns during the pubertal growth spurt and dropout rates, burnout, bone health and overuse injuries later in life.
- This approach has particular future scope in consideration of wider child and youth population health issues namely obesity, diabetes, mental health and other cardiovascular diseases where enhanced physical development could lead to improvements in health and wellbeing and greater participation levels.

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Appendices

Appendix 1

All participants training content details are in table I –

Table I

Age Groups	Soccer Specific Training	Strength & Conditioning Training	Physical Education Class
Under 11	3 x 90min Plus Match	3 x 30min	2 x 40min
Under 12	4 x 90min Plus Match	3 x 30min	2 x 40min
Under 13	5 x 60-90min Plus Match	4 x 30min	2 x 40min
Under 14	5 x 60-90min Plus Match	4 x 30min	2 x 40min
Under 15	5 x 60-90min Plus Match	4 x 40min	2 x 40min
Under 16	5 x 60-90min Plus Match	4 x 40min	2 x 40min
Under 18	5 x 40-80min Plus Match	7 x 20-60min	0

Appendix 2

Normative values of functional competence, speed and lower body power for soccer playing children at different stages of developmental age.

PARTICIPANT INFORMATION LEAFLET

My name is Des Ryan. I work in the fitness department in the Arsenal FC I am inviting you to take part in a research project entitled '**Normative values of functional competence, speed and lower body power for soccer playing children at different stages of developmental age'** Thank you very much for your assistance and time with this research project. Please read the following paragraphs, which should explain the research in detail.

What is this research about?

This research is being carried out in order to evaluate functional competence (Mobility and Stability), speed and jump ability in young rugby players at different stages of development to assist in the identification of important areas to help develop the player at different stages of development.

Why are you doing this research?

We are doing this research to assess functional competence (Mobility and Stability), speed and jump ability in young rugby players at different stages of development. This will allow us to gain a greater understanding of the needs of the young player which will in turn will help design more appropriate training programmes for the player.

How will the data be used?

The results we obtain from the study will be used for a number of purposes:

- Results will be analysed from the different tests and compared to other players to establish average scores for this age group.
- When the study is complete we intend to submit the grouped results to a scientific journal for publication.

What will happen if I decide to take part in this research study?

Your/Your Childs participation in this investigation will involve you attending and participating in the screening day in Arsenal Academy on the date listed in the introductory letter and providing permission for the use of the data generated from the tests. The tests involved are described below and the entire process will take in the region of 2 hours per player. You/Your Child will be given ample time and instructions from staff to practice tests prior to the actual test.

1. Questionnaire – a questionnaire is enclosed in this package requesting details relating to emergency contacts, your previous injury history, medical history and access to medical staff.
2. Functional Screening –
   a) Deep squat – This movement involves squatting with a broom handle over head lower as possible.
   b) Hurdle Step – This movement involves stepping over a hurdle with both legs while holding a broom handle on the players shoulder.
   c) In Line lunge – This movement involves stepping into a lunge position while holding a broom handle along your back.
   d) Shoulder Mobility – This involves reaching both hands behind the players back one from above and one from below and trying to get as close as possible.
   e) Active straight leg raise – This involves raising your leg up to as close to a 90 degree position as possible.
   f) Trunk stability – This involves completing a push up movement for three repetitions.
   g) Rotational stability – This involves standing on all fours and reaching out with one leg and one arm.

3. Fitness Screening
   a. Countermovement (CMJ) jump - This test measures explosive leg power from a dynamic counter movement. You will be asked to complete a three CMJ on a pressure sensor that records the height you jump and the duration of the jump.

b. 10m & 30m Sprint – This test measures your acceleration speed and flying speed from a stationary start. You will be asked to sprint a 10m and 30m distance with maximal effort between two points and the time will be recorded.

How will you protect my privacy?

Your results from this study will be stored on an password protected computer held by Mr. Des Ryan (Arsenal FC). Your name will be given an individual code on a master sheet, which will be held in confidence by the lead investigator (Des Ryan). Following the input of your data into a computer database, your study code number will appear on all study documentation from there onwards.

What are the potential benefits of taking part in this research study?

Identification of strengths and deficits in functional screening and fitness tests will provide us with a greater understanding of the fitness requirements of Academy players of your age, as well as providing staff with the opportunity to observe potential injury risk factors and devise appropriate rehabilitation/training programs for soccer players.

What are the risks of taking part in this research study?

As with all functional screening and fitness tests, some risk is associated with participation in this study. However, all tests will be conducted by experienced, trained staff in a controlled environment. Only players deemed fit to participate by medical staff will take part in the testing. Tests have been previously used and are detailed below. Furthermore tests explained extensively and demonstrated to you by staff at the screening day.

The risks are as follows – Like all training sessions there is the risk of injury. There will however be no contact just running and jumping activities with a small risk of muscular injury.

Can I change my mind at any stage and withdraw from the study?

Your participation in this research is voluntary. You are free to withdraw from this study at any stage and for any reason that you see fit. You may still attend the camp and participate in the screening tests and not have your results included in any study.

How will I find out what happens with this project?

A report on the study will also be written and may be submitted for publication in a scientific journal. This report will not contain any information that could be used to identify individual identity or results. If you wish you may request a copy of the report on completion.

Contact Details:

Des Ryan (Head of Sport Medicine & Athletic Development Arsenal Academy), 07860400751 dryan@arsenal.co.uk

____

PLEASE SIGN ABOVE FORCONSENT

PARTICIPANT INFORMATION LEAFLET

My name is Des Ryan and along with your coach I would like to ask you to complete the following activities to help develop you as a soccer player.

The purpose of the activities is to see what are the areas a young player needs to improve and what are the normal standards are for a young rugby player at different ages. The information will be published but your name will not be used.

Please sign your consent below

……………………………………	……………………	………………………..
Name of Participant (in block letters)	Date	Signature
……………………………………	……………………	………………………..
Name of Parent/Guardian	Date	Signature
……………………………………	……………………	………………………..
Researcher	Date	Signature

I declare I am medically fit to participate in this study

……………………………………	……………………	………………………..
Name of Participant (in block letters)	Date	Signature

Appendix 3

Reasons for Testing

A summary of the main reasons for fitness testing are as follows:

(1) To develop an individual physical and fitness profile. The aim is to identify a player's strengths and weaknesses. This can be done through a series of general stability, functional and physical performance tests and sport specific tests. Short-term and long term fitness goals can then be established.

(2) To evaluate objectively the effect of a specific programme. The ultimate aim of fitness training is to improve performance on the field of play. Baseline test measurements are best collected before the start of a programme and then at intervals throughout the season. A period of 6-8 weeks is ideal between pre-season 1 and pre-season 2 testing occasions. It is recommended to establish four rounds of comprehensive fitness testing each year as a minimum standard. This will provide a method of assessing the effectiveness of the training completed during the pre-season and the status of fitness during mid-season and prior to the any major Championship or Tournament.

(3) To monitor progress during rehabilitation. In the event of injury a player's predetermined fitness profile will be valuable in monitoring the progress of recovery. This has implications for ensuring stability and proprioceptive competencies are returned to normal before addressing functional and performance competencies. It is important for both player and team coach to know how a player is responding following injury. It is well established that players who return to injury prematurely (and who display elements of instability, poor dynamic function and low performance scores) run the risk of a recurring injury.

(4) To provide valuable research information. Fitness testing data can provide much valuable information when assessing and comparing the effectiveness of different training programmes, training devices and interventions. Several advances in performance science rely on using both laboratory and field based tests to elucidate the effectiveness of a training intervention.

The following are some key points in relation to fitness testing:

1. A test should never be used without a purpose or reason.

2. Except for Stability, Functional tests and basic fitness tests all performance Tests need to be appropriate to the game or Sport (i.e. valid).

3. Tests should also display a high degree of reliability.

4. Tests should be appropriately administered (i.e. the tester must show a high degree of (reliability) from one occasion to another).

5. The test administrator should have experience at interpreting tests results.

6. Direct feedback should be given to the player, preferably on an individual basis.

7. If inter-player comparisons are to be made allometric modelling is recommended as an effective method of correcting for body mass.

Selecting a Valid Test

Once the reason for testing has been clearly defined an appropriate test must be selected. As mentioned a test must be valid. A valid test is considered one that displays good "face validity" (in other words it must be obvious how it relates to a movement or action in the game) or it must display a strong relationship to the general qualities required to play a sport. For example, a high score in the Counter Movement Jump (CMJ) is strongly related to acceleration and maximum velocity. Good acceleration in a key quality required to perform high-intensity football and so the CMJ is a valid test for assessing indirectly this fitness capacity in the football player. It has been shown that changes in all power tests used (CMJ, SJ, Squat and Clean) are positively related to improvements in acceleration and horizontal drive power (Reference). As a result we can confidently state that Positive changes in these tests transfer to improvements in speed and power – key qualities required to play football.

Stability and Functional tests are somewhat different in that the purpose of assessing Stability and Functional competence is to determine if the player has the basic stability and movement competencies required to commence intensive training. A key point is that the functional stability tests selected replicate common movements completed on a daily basis for the player and display high face validity.

TEST RELIABILITY

The reliability of a test demonstrates the extent to which a test can be reproduced on different occasions. Good 'test' reliability is important if changes, due to training effects, are to be assessed and normative values can be assessed. Test-retest reliability has been established for the author who has administrated all the anthropometric tests, Functional competence and physical performance tests.

Anthropometric tests

Measurements Protocols

Need to measure and record the following: body mass (kg) and standing height (cm)

A. Body Mass – Weigh subject with minimal clothing and with shoes removed.

1. Check the scale is reading zero

2. Ask subject to stand on the centre of scales, without support and with their weight distributed evenly on both feet – record body mass to nearest 0.1 kg.
3. Ask subject to step off the scale
4. Repeat steps 1 to 3
5. If the 2 measurements differ by more than 0.4 kg then repeat steps 1 to 3
6. If two measurement record the average value. If three measurements record the median value.

B. Standing Height – Use the stretch stature method. Stature is the maximum distance from the floor to the vertex of the head. The vertex is defined as the highest point on the skull when the head is held in the Frankfort plane. This position is when the imaginary line joining the orbitale to the tragion is perpendicular or at a right angle to the long axis of the body. Subject is measured with shoes removed.

1. Ask subject to stand with back, buttocks and heels against a stadiometer. Subject's feet should be together and flat on the floor.
2. Place subject's head in the Frankfort plane (Figures 1 & 2). Place your hands far enough along the line of the subjects jaw to ensure that upward pressure is transferred through the mastoid processes.
3. Instruct subject to take and hold a deep breath. While keeping the head in the Frankfort plane apply gentle upward lift through the mastoid processes. At the same time place the headboard firmly down on the vertex, crushing the hair as much as possible. Ensure that the feet do not come off the ground and that the position of the head is maintained in the Frankfort plane.
4. Record measurement at the end of the subject's deep inward breath – record stature to the nearest 0.1 cm.
5. Ask subject to step away from the stadiometer
6. Repeat steps 1 to 4
7. If the 2 measurements differ by more than 0.4 cm then repeat steps 1 to 4

8. If two measurement record the average value. If three measurements record the median value.

C. Sitting height – Use the stretch stature method. Sitting height is the maximum distance from the vertex to the base of the sitting surface.

1. Seat subject on a measuring box or level platform (of known height) with their hands resting on their thighs
2. Instruct subject to take and hold a deep breath. While keeping the head in the Frankfort plane (Figure 2) apply gentle upward lift through the mastoid processes. At the same time place the headboard firmly down on the vertex, crushing the hair as much as possible. Ensure the subject does not contract the gluteal muscles nor push with the legs.
3. Record measurement at the end of the subject's deep inward breath – record sitting stature to the nearest 0.1 cm.
4. Ask subject to step off the box and away from the stadiometer
5. Repeat steps 1 to 4
6. If the 2 measurements differ by more than 0.4 cm then repeat steps 1 to 4
7. If two measurement record the average value. If three measurements record the median value.
8. If using a floor stadiometer the observed height minus the box / platform height is the sitting height.

D. Leg Length = Standing Height (cm) - Sitting height (cm)

Below is a description of the test and the protocols for the CMJ test.

Purpose:

This test aims to determine the explosive leg power of the player from a dynamic counter movement. This test correlates highly with initial acceleration and speed over 30 metres. It also displays good face validity with jumping actions during field games. In addition it is a reliable if general marker that tracks recovery during training and playing. Used in conjunction with other physical and psychological markers it is a very useful player recovery status marker.

Practice Instructions:

Player should practice the following before attempting CMJ

Maintain hands on hips throughout the jump.

Self-select the counter movement - but not a very small counter movement.

Then Jump vertically as high as possible.

Land with toe/forefoot down first and then after landing bounce up and down to ensure straight leg landing.

It is important to have all players practice the correct jump and landing technique before testing

Ensure that they land with toe-fore foot down without bending knees.

Maximal effort jumps are required.

The player must practice 3 sub maximal jumps to ensure that technique is correct

Then the player should practice 3 maximal jumps prior to attempting the test

Player Instructions:

- The purpose of this test is to assess your leg power.
- You must concentrate fully on the correct technique while aiming to jump as high as possible.
- Place your Hands on your hips and maintain hands on throughout the jump test.
- Stand on the mat and when you are ready countermove to jump as high as possible.
- Land in the area that you jumped from using the bounce technique.

Administrator guidelines for CMJ:

- Observe the jump from a 30 degree angle and to the side.
- Common faults in the execution of the CMJ are piking during the jump, heel kicking, hands coming off hips, heel landing, landing too far forward.
- Be observant and if the technique is not satisfactory inform the player and repeat.

(Hennessy et al., 2010)

Below is a description of the test and the protocols for the Speed test.

Purpose:

- The purpose is to assess acceleration speed from a stationary start. The distances selected represent the distance most frequently covered during a game at maximum pace. Typically, they vary between 5-25 metres (Burgees, et al. 2006). This means that acceleration is a key ‘speed’ component required in the game of Soccer.

Distances covered:

- 0-10 metres. Indoors on synthetic track.
- It is essential to ensure that the distances are double checked prior to testing.

<u>Using Timing Gates</u>

Set-up:

- Height: Placed at 95 cm from ground level to light
- Distance between gates: Lane width + 20 cm each side
- Starting line: A standing start 0.7 metres behind the timing gate. Tape lines at 0.7 and 0 start.
- Body position: No sway or countermovement allowed.
- Start signal: Player starts on his own volition.
- Finish: Place two cones 5 metres after finish gates

Warm-up:

- Prior to this test the player may have completed CMJ tests. Nevertheless a thorough warm-up must take place.
- Sub-max accelerations over 30 metres at 50%-60%-70%-80%-90% efforts. With slow walk back and light stretch recovery.

Test procedure:

- As the individual who supervises the test ensure that you are within 5 metres of the start at all times.
- Supervise the start position and ensure compliance.
- Ensure that each result is recorded immediately after the trial and before the next player assumes the start position.
- Brief all players as to the start position before the test. Ensure that all players practice this during the sub max warm-ups.

Test interval:

- Each player completes 2 maximum effort trials with a minimum of 3 minutes rest between trials. Players may have a third trial if necessary. However, no more than three should be allowed.

Results:

- Two trials with the best from both recorded as the result.
- Record results on your score sheet as follows:

Name	**0-10**	**0-10**
A Ball	1.44	1.43

- Present the results on excel as follows:

Name	**10mJune00**
A Ball	1.

Player test Instructions:

- Your start must be from a Stationary standing position without any swaying motion
- You must get into a forward lean position and hold it.
- Start when you are balanced and ready.
- You must sprint at Maximum effort.
- No slowing down.
- Sprint through to the 5 metre cones placed beyond the finish line.

(Hennessy et al., 2010)

Appendix 4

Standardised Warm Up

20m 20m 20m – Yellow poles and each 10m

5minutes continuous below

Jog (20m)

Jog (20m)

Stride (20m)

10min below

(1) Arm swing and skip – Jog Back
(2) Arm swing across – jog back
(3) Across and high knee carioca – jog back each side
(4) March B skip – quad stretch back
(5) Over gate – hug knee
(6) Leg kick and clap under – hug external rotation
(7) Lunge high knee – Skip touch external rotation
(8) Squat jog – calf stretch
(9) Stride out – stride back
(10) High Knee march – jog
(11) High Knee Skip – jog
(12) Po go – walk back
(13) Single leg hop double
(14) Stride out
(15) Sprint first pole half turn sprint second pole half turn sprint – walk back
(16) As above
(17) As above
(18) As above