THE EFFECT OF AGE AND MATURATION ON ANTHROPOMETRIC CHARACTERISTICS AND PHYSICAL ABILITIES OF YOUTH SOUTH AFRICAN FOOTBALLERS

BY

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ABSTRACT

Currently there is limited research investigating the football related abilities of youth South African individuals. Populations from North and South America, Europe and Asia have been extensively covered in terms of their anthropometric characteristics, physical abilities, technical competency, tactical understanding as well as various personality traits. In describing these details, and especially how each is affected during the ageing and pubertal process, a more informed understanding of the talent development systems is created. A holistic approach to talent development is required to effectively and efficiently produce elite level footballers. An important consideration is the unique socio-economic environment many youth footballers experience which may impact on the talent development process. The present study therefore sought to quantify the anthropometric characteristics and the physical ability level of youth South African footballers from Local Football Association in Makhanda in the Sarah Baartman Region of the Eastern Cape province.

In order to achieve this a two-factorial design was used with age and maturity status as independent variables. Anthropometric characteristics were tested by finding the height, weight, body mass index and total fat percentage of participants. Physical ability was determined by results for aerobic capacity, power, acceleration, speed and agility. All tests were football specific and had been widely used in a variety of footballing studies. Additional demographic and socio-economic information was also recorded. A total of 136 participants were placed in their respective Under 11, 13, 15 or Under 19 age groups, while the maturity status of 96 participants were stratified into five distinct categories. Statistical analyses was conducted using p-value significance, with appropriate Tukey post-hoc tests administered when necessary, while effect sizes were calculated using Cohen’s d.

Significant changes and practical effect sizes were present for nearly all dependent variables when either stratified by age or by maturity. Total fat percentage was the only dependent variable which was not influenced by either age or maturity. Age and maturity effect sizes for total body fat percentage indicated practical changes present which did not occur during statistical analysis. The present results indicate poor values when compared to normative data or that of other football playing study populations. Further longitudinal research is required to better understand individual growth rates for youth South African footballers, particularly from the Makana region. Implications of the thesis may determine long term development pathways, while the delayed maturity rate is a critical finding which needs to be further researched.

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CHAPTER I: REVIEW OF LITERATURE AND PROBLEM IDENTIFICATION

1.1. Introduction

Football is the most popular sport in the world, played by over 200 million people (Dvorak & Junge, 2000), with each nation imparting their own unique identity upon the game. It is no different in South Africa were approximately 4,5 million players are involved with football (FIFA Big Count, 2006). This makes the sport a vital area of interest for youth development especially with nearly 165,000 youth players, under the age of 18, participating yearly (FIFA Big Count, 2006).

Sporting development is a multidimensional pathway with an athlete being broadly influenced by numerous factors which are both personal and environmental in nature (Tucker & Collins, 2012). Youth athletic development is dynamic and non-linear with each athlete experiencing afore-mentioned factors differently (Bailey, Collins, Ford, MacNamara, Toms, & Pearce, 2010). From a South African perspective these factors are potentially compounded by the socio-economic context perpetuated by the historical background of the country. Consequently, within the framework of sports development research an explanation of the current socio-economic status of South Africa, along with the structures of the South African Football Association, are important factors for consideration.

Understanding the rate and timing of an individual's maturity status is fundamental when training youth athletes. Every athlete matures differently and applying the same training or selection criteria will give a misrepresentation of a youth athletes ability (Meylan, Cronin, Oliver, & Hughes, 2010). Currently, a lack of research on the developmental process, and the effects of maturity, on anthropometric and physiological characteristics of youth South African footballers is present. Without research identifying the necessary maturity points of South African footballers, the correct developmental model cannot be created. Investigating what research has identified about youth footballers is an important step forward and may allow additional research to be created.

Therefore, the following section on relevant literature will include:

1. Literature relating to youth talent identification and development models which are applicable in a sporting context.
2. Components of football necessary to achieve success and the impact of maturity upon these components.
3. Review of South African football literature and a detailed description of the socio-economic environment.

This review will be followed by a clear identification of the gaps in the literature that will be used as the basis for the research problems identified for the current research.

1.2. Review of Literature

1.2.1. Defining Talent Identification, Development & Excellence

Talent identification (TI) is described as the process of recognising youth athletes who have the potential to achieve elite expertise (Williams & Reilly, 2000). While talent development (TD) refers to the provision of appropriate coaching and creating an environment which will allow a youth athlete to fulfil their potential (Vaeyens, Lenoir, Mark, Williams, & Phillippaerts, 2008). The attainment of elite expertise, and the manner in which it is identified and developed, is a complex issue with multiple influencing factors resulting in multiple theories.

Miller and Kerr (2002) defined excellence two ways: Elite Referenced Excellence (ERE) and Personal Referenced Excellence (PRE). ERE is the attainment of elite level sporting competition, while PRE is achievement of personal performance or participation. A third category was proposed more recently by Bailey *et al*. (2010) of Participation of Personal Wellbeing (PPW), whereby sport is conducted to satisfy personal goals outside of achievement. Examples include using sport to make friends, maintain self image, or enhancing an individuals identify or social life (Bailey *et al.*, 2010). In acknowledging the variety of forms athletic excellence can occur in, a clearer idea of talent development can be constructed. The unpredictability of athletic development has been illustrated extensively in research, indicating how a single solution to talent development is not possible (Martindale, Collins, & Daubney, 2005;

Vaeyens *et al.,* 2008; Bailey *et al.*, 2010; Li, Wang, & Pyun, 2014; Johnston, Wattie, Schorer, & Baker, 2017). Athletic development is non-linear and dynamic with individuals able to take various pathways to achieve athletic excellence. A rigid pathway is unlikely to cater for all individuals as the timing and tempo of development cannot be predicted (Bailey *et al.,* 2010).

Calculating the interaction affect between domains is an unquantifiable action, with many interpretations and explanations being presented as factors which influence youth development (Williams & Reilly, 2000; Gagné, 2000; Tucker & Collins, 2012; Mills, Butt, Maynard, & Harwood, 2012; Suppiah, Low, & Chia, 2015; Lloyd, *et al*., 2015a). An exhaustive list of possible influencing factors is difficult to ascertain, further complicating effective talent development programs.

Talent identification and development literature has historically used a standard model to describe the process of TID (Bailey *et al.*, 2010). Recent literature has contended for a more nuanced understanding which utilises a multidimensional approach. Several issues have been raised about the standard model which question the efficacy of the model and its purported benefits. The sections that follow provide an explanation for firstly the standard model of TD, and then newer multidimensional models.

1.2.2. Standard Model of Talent Development

The pyramid, or standard model, is a common model of talent identification and development (Abbott, Button, Pepping, & Collins, 2005; Bailey & Collins, 2013). The creation of the standard model has been the result of organisations and teams following a series of proponents which underpin the model and how it is utilised.

Once identified, individuals progress up the pyramid through different talent bands within a diminishing, yet more competitive, pool of talent, as illustrated by Figure 1 (Bailey & Collins, 2013). Initial broad, foundational skills are improved as progression allows enhanced access to better coaching (Bailey & Collins, 2013). Consequently, this model is also known as the individualistic approach whereby considerable resources are directed towards fewer athletes to help realise their full potential (Vaeyens *et al.,* 2008; Güllich, 2014).

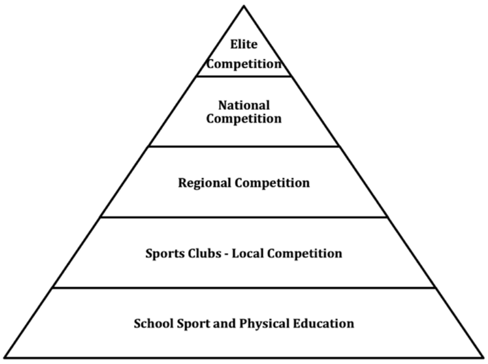


Figure 1: The Standard Model of Talent Development (adapted from Bailey and Collins, 2013)

The proponents of the standard model contend that in practical terms several characteristics help construct the Standard Model of Talent Development:

1) Identifying talented individuals at a young age allows increased training time, otherwise known as deliberate practice. Specialisation in one sport can occur resulting in improved performance (Jayanthi, Pinkham, Dugas, Patrick, & LaBella, 2012; Bailey & Collins, 2013).
2) Specific screening criteria are used to select talented individuals (Helsen, Hodges, Van Winckel, & Starkes, 2000; Bailey & Collins, 2013). Factors have traditionally centred on physical capabilities (Helsen *et al.*, 2000).
3) Identified athletes are progressed to the next level of competition, normally at the expense of other youth athletes (Williams & Reilly, 2000; Bailey & Collins, 2013).
4) Deselected athletes are removed from the system and no longer participate in the same structure as selected athletes (Bailey & Collins, 2013).
5) Thus, deselected athletes find it difficult to return to a given sport at a later point (Bailey & Collins, 2013; Pankhurst & Collins, 2013).
6) Finally, performance can be maintained from a young age to elite level competition (Bailey & Collins, 2013; Pankhurst & Collins, 2013).

The following section will unpack these characteristics in more detail. Firstly the key tenants of the each characteristic will be presented followed by a critique as proposed by relevant literature.

1.2.3. Deliberate Practice, Early Specialisation & Selection Criteria

The standard model argues that for successful performance to occur a significant amount of time should be invested to training (Bailey & Collins, 2013). This is referred to as deliberate practice and there are 3 foundational characteristics of deliberate practice (Bailey & Collins, 2013). These are:

1) Elite athletes will specialise in a chosen sport earlier,
2) Which allows for earlier engagement with deliberate practice (Bailey & Collins, 2013).
3) Resulting in more practice hours accumulated (Côté, Baker, & Abernathy, 2007).

An early study by Simon and Chase (1973) investigated the application of deliberate practice on world class chess players performance, establishing the 10 year or 10,000 hour rule. The theory contends that engaging in sustained, deliberate practice over an athlete's teenage years would allow the accumulation of enough practice time to gain expertise (Ericsson, Krampe, & Tesch-Römer, 1993). An additional study on violinists found the average time to reach a master level was 10,000 hours by the age of 20, supporting the original hypothesis (Ericsson, Krampe, & Tesch-Römer, 1993).

Early specialisation of a singular sport, through the deliberate practice framework, allows the nuances of it to be better learnt and those who dedicate themselves, by inputting enough practice time to improve their skills, will be rewarded (Vaeyens, Güllich, Warr, & Philippaerts, 2009, Suppiah, Low, & Chia, 2015). Youth athletes will have renewed confidence in their ability to succeed followed by greater application, in an ever continuing cycle until an athlete is de-selected (Pankhurst & Collins, 2013). A correlation between achieved performance level and the amount of deliberate practice an athlete accumulates is evident (Helsen *et al.*, 2000; Baker & Horton, 2004; Côté, Baker, & Abernathy, 2007; Malina, 2010; Jayanthi *et al.,* 2012).

Screening tools traditionally focus on the physical and anthropometric characteristics of youth athletes (Burgess & Naughton, 2010; Unnithan, White, Georgiou, Iga, & Drust, 2012; Pankhurst & Collins, 2013; Bailly & Collins, 2013). Position specific anthropometric and physical requirements will differ between sports at an elite level (Pearson, Naughton, & Torode, 2006). Thus, early categorisation of a young athletes potential to fit certain anthropometric profiles is required to best aid development (Meylan *et al*., 2010). Coupled with a coach or selector who fosters a 'win now' attitude to youth competition, will result in the selection of individuals who possess anthropometric or physical advantages over their peers (Malina, 2010). Furthermore, promotion of talented individuals is judged on their competition performances which is heavily influenced by their physical advantage, particularly at younger age groups (Malina, 2010; Bailly & Collins, 2013, Suppiah, Low, & Chia, 2015).

1.2.4. Critique of Deliberate Practice, Early Specialisation & Selection Criteria

The role of deliberate practice underpins the 6 characteristics of the standard model of talent development (SMTD). In detailing the limitations in the deliberate practice framework, and possible problems when developing talent, the argument for the standard model of development can be weakened.

The validity of deliberate practice has been contested as it oversimplifies the average time needed to achieve mastery (Pankhurst & Collins 2013). The original study by Simon and Chase (1973), and subsequent studies, did not account for the standard deviation present through human variability (Tucker & Collins, 2012). It is equally possible an athlete may achieve elite level performance after only 5,000 hours while others take 15,000 hours or more. The dynamic nature of talent development makes it difficult to determine the exact duration needed to achieve sufficient expertise in a given sport (Reilly, Williams, Nevill, & Franks, 2000; Abbott, Button, Pepping, & Collins, 2005; Vaeyens *et al.,* 2008). However, an Ericsson editorial response (2013) discussed how the attainment of elite level can happen in a much shorter time frame, suggested as between 4000-6000 hours (Pichardo, Oliver, Harrison, Maulder, Lloyd, 2018). This stance is in accordance with research published by Baker and Young

(2014) who clarify the quality of the deliberate practice is more important than the quantity (Pichardo *et al.,* 2018).

In essence this may be seen as a self-fulfilling system, whereby administrators are able to keep selecting the dedicated, or fortunate, individuals into smaller talent pools (Vaeyens *et al.,* 2008; Bailey & Collins, 2013). Individuals who attain elite level are then used as evidence to support the model (Pankhurst & Collins, 2013). However, limited information is kept on de-selected players career paths and the consequences individuals face once removed (Bailey & Collins, 2013). With a large enough player base the naturally talented individuals will become apparent and progress (Vaeyens *et al.,* 2008). The success rate of players achieving elite status from academies or youth development programs is a very small percent, indicating the difficulty in determining potentially talented adult athletes at a young age (Jayanthi *et al*., 2012).

Furthermore, particularly in a South African context, the access to both coaches and facilities is a crucial area of concern. The ability to participate is a potential limitation and certain individuals may have an advantage based on their socio-economic standing (Bailey *et al.,* 2010; Bergeron, Mountjoy, Armstrong, Chia, Côté, Emery, Faigenbaum, Hall, Kriemier, Léglise, Malina, Pensgaard, Sanchez, Soligard, Sundgot-Borgen, van Mechelen, Weissensteiner, & Engebretesen, 2015). Socio-economic factors may influence access to coaching or attending practice as well as the school a child may attend (Bailey *et al*., 2010; Li, Wang, & Pyun, 2014; Bergeron *et al*., 2015).

Additionally, one dimensional screening tools which focus on physical capacity can misrepresent the talent level of an individual (Vaeyens *et al*., 2009; Güllich, 2014). The problem arises in focusing on such factors too early in a youth athletes career whereby a false dichotomy of talent is created with those fitting the supposed profile being favoured (Abbot *et al.,* 2005; Vaeyens *et al.,* 2008; Unnithan *et al.,* 2012; Tucker & Collins, 2012; Pankhurst & Collins, 2013).

Pertinently, potential negative ramifications can arise from attempting to attain elite performance. The notion of sustained practice is an area of concern as it places a considerable stress on a young athlete (Vaeyens *et al.,* 2008). Removing the strict necessity of deliberate practice can have substantial benefits for youth athletes (Côté, Baker, & Abernathy, 2007; Vaeyens *et al.,* 2008; Suppiah, Low, & Chia, 2015). The risk of burnout, both psychological and physical, are reduced in youth athletes (Côté, Baker, & Abernathy, 2007; Vaeyens *et al.,* 2008; Pankhurst & Collins, 2013). Enjoyment of the sport can be decreased if there is a win at all costs mentality (Bailey *et al.*, 2010).

Criticism of the standard model of talent identification focuses on a number of aspects, namely; the use of an individualistic approach containing an over-reliance on physical characteristics to identify talent, with the subsequent implementation of extensive deliberate practice while not accounting for relative age affects (RAE) and maturity rates (Vaeyens *et al.,* 2008; Unnithan *et al*., 2012; Pankhurst & Collins, 2013; Güllich, 2014).

1.2.5. Summary

In summary, the criticism of the standard model can be described as;

1. Deliberate practice has not been shown to work in an efficient manner. Rather, it produces a more haphazard outcome whereby early identified individuals have a much greater possibility of achieving success.
2. Burn out, both physical and mental, are commonly associated with DP and SMTD due to excessive practice at an early age. This can cause problems for youth athletes, such as experiencing mental fatigue, injuries, lack of motivation and dedication.
3. The systematic exclusion of young players leads to participants not returning to the sport, with decisions being based on limited information.
4. Exclusion of athletes is due to the excessive focus of physical attributes. All individuals develop at different rates and this unpredictability should be monitored to better reflect a youth athlete’s capacity. Periods of fast and slow progression

will be evident and once off measures are not adequate for effective talent development.

1.2.6. Theories of Development & Multidiscipline Models

Due to the aforementioned critiques of the standard model, newer models have been developed. Different models and theories have been developed placing an emphasis on multidiscipline development (Bailey *et al.*, 2010). Each of these models attempt to reduce the potential risk of physical or mental burnout, while also effectively developing talent (Bailey *et al.*, 2010). Additionally, different models utilise either literature, experience or empirical evidence to inform decisions (Bailey *et al.*, 2010). The multidiscipline models and theories presented are specific to talent development within a general sporting context, from theoretical underpinnings of holistic talent development into more practical applications and examples of how to nurture youth athletes.

1.2.6.1. Review of Multidimensional Theoretical Models

Bailey *et al.* (2010) outline a few multidimensional models of ability including:

- Marland's (1972) Areas of Achievement or Ability
- Gardener's (1983) multiple intelligence model
- Perleth and Heller's (1994) Munich model of Giftedness and Talent
- Gagné's (2004) Differentiated Model of Giftedness and Talents.

For the purpose of this review, the discussed models are widely used and encompass both theoretical and practical outcomes.

Sporting performance is a complex system, with the likelihood of attaining expertise limited when only focusing on the singular development of a certain skill (Baker & Horton, 2004). The learning of new skills, in different domains, allows a multiplicative effect to occur (Simonton, 1999). A positive development in either anthropometric, physical, physiological or cognitive abilities will have a beneficial impact on the development of other components (Simonton, 1999). Although there is a multiplier effect in skill development it can be difficult to ascertain the direct causes of this development (Bailey *et al.*, 2010). Therefore, it is imperative individuals develop varied skills to enhance their innate abilities and maximise their potential (Bailey *et al.*, 2010).

1.2.6.2. Differentiated Model of Giftedness and Talents - Gagné

Gagné's (2004) Differentiated Model of Giftedness and Talents (DMGT) is a multidiscipline approach for long-term development. Giftedness refers to superior natural abilities an individual possesses relative to their peers (Gagné, 2004). Conversely, talent is the systematic development of such gifts or abilities which elevate an individual into an elite level position (Gagné, 2004). Gagné (2004) proposes a gifted individual is one who possess an ability, in a singular domain, which places them within the top 10% of their age group. According to this model gifted abilities are more recognisable in children, as their abilities are a product of genetic expression without the influence of environmental factors. The challenge is aligning those gifted abilities with the right environmental and learning processes.

Under Giftedness, there are four domains: intellectual, creative, socioaffective and sensorimotor. Intellectual ability involves using fluid reasoning such as induction or deduction, spatial awareness, memory and metacognition. The creative domain contends with problem solving in inventive ways, imagination or originality in the arts. Socio-affective domain relates to communication with others, influence with regards to leadership as well as perceptual intelligence. While the sensorimotor domain is indicative of visual, auditory or olfactive abilities while also encompassing strength, endurance reflexes or coordination. Each individual will possess a wide range of abilities in each of these subsections, to which the list is extensive (Vaeyens *et al.,* 2008).

Through the developmental process of formal and informal learning, along with practice, talents can be refined and trained (Vaeyens *et al.,* 2008). Additionally, gifts can manifest themselves in a variety of fields and activities within a unique set of combinations (Gagné, 2004; Vaeyens *et al.,* 2008). According to Gagné (2004) an individual cannot be talented without first being gifted. Talent is achieved through the conscious engagement in learning or practice; the opposite is the unfilled talent of naturally gifted individuals. The facilitation of the developmental process is dependent on interactions between certain catalysts as well as the presence of chance.

Catalysts are split into two broad sections, either intrapersonal or environmental (Gagné, 2004; Vaeyens *et al.,* 2008). Intrapersonal consists of both physical and psychological catalysts (Gagné, 2004; Vaeyens *et al.,* 2008). Physical catalysts refers to the anthropometric or health related in which genetic hereditary is an important factor (Gagné, 2004; Vaeyens *et al.,* 2008). Psychological factors are detailed as motivation, volition, self management and personality (Gagné, 2004; Vaeyens *et al.,* 2008). Possessing inherent motivation to overcome and maintain development is crucial as is having the correct temperament, levels of concentration and will power to succeed (Gagné, 2004; Vaeyens *et al.,* 2008).

An individual's milieu, persons, provisions and events constitute the environmental catalysts (Gagné, 2004). Milieu is the geographic location of a youth athlete while acknowledging the socioeconomic status of the family and area (Gagné, 2004). Persons are the positive or negative impact a family member, teacher, coach or friend may have on a child (Gagné, 2004). Provisions in a footballing context would be the availability of fields, team, leagues but also the academic provisions in terms of level of schooling available. Finally, an Event is any positive or negative outcome which shapes a young athlete, winning awards in a given sport or incurring any serious injuries are examples (Gagné, 2004; Vaeyens *et al.,* 2008). Chance as the 5th factor, where the chance of being born into a family with high socioeconomic resources, is a considerable advantage (Gagné, 2004). Genetic heredity is attributed to chance as a youth athlete may receive, in addition to working with the right coach (Gagné, 2004).

Gagné's model (2004) is a framework to base future talent development work from, however it does have its limitations. Currently the model is a theoretical outlining of the potential influences on talent development (Vaeyens *et al.,* 2008). Further studies are required to describe the extent to which each domain exerts a positive or negative contribution on a youth athlete.

1.2.6.3. Deliberate Play & the Development Model of Sports Participation

Côté (1999) provide rational, based on detailed interview history of elite athletes, on how deliberate play is a fundamental step in nurturing talent. Deliberate play is described as an 'early sporting activity involving developmental physical activities which are intrinsically motivating, provide immediate gratification and designed to maximise enjoyment' (Côté, Baker, & Abernathy, 2007). By encouraging deliberate play the pressures of intensive, structured practice and competition are alleviated, allowing youth athletes to practice a range of different skills and techniques (Côté, Baker, & Abernathy, 2007). This is substantiated by an earlier study (Pellegrini & Smith, 1998), that found deliberate play to provide foundational skills improving an individuals physical, cognitive and social abilities within a variety of contexts and situations.

According to Côté, Baker, & Abernathy (2007) the main supporting argument for deliberate play is how past elite athletes spent a considerable portion of their youth recreational time playing adapted versions of different sports. These adapted versions, such as backyard sports, increases creativity and allows for more flexible cognitive strategies to be created. Deliberate play can range from fundamental actions such as shooting technique too complex actives such as small sided games adapted rules. Thus, young athletes are able to experiment with a variety of skills, with minimal resource input and no coach or adult supervision. Furthermore, the time on task for deliberate play will increase substantially as deliberate play can encompass a wide variety of activities. A good example is two on two basketball whereby individuals are constantly active and engaging in a variety of tasks and roles. As the score is of limited importance, the activity is done more for the enjoyment. Consequently, a more positive relationship with sport is fostered which increases an individual's motivation and willingness to participate in structured activities. Gilbert, Côté, Harada, Marchbanks and Gilbert (2002) describe athletes who partake in greater amounts of deliberate play between the ages of 6-12 where more likely to engage in specific, deliberate training after the age of 13.

The model developed by Côté, Baker and Abernathy (2007) - the Developmental Model of Sports Participation (DMSP) - advocates for both effective and efficient talent development. This model is influenced by learning effectiveness and efficiency, as described by Wulf and Shea (2002). Learning effectiveness relates to the factors which influence motor skill development while learning efficiency does the same but at a lesser cost to the learning process (Wulf & Shea, 2002). The cost of learning, in a talent development situation, is any negative effect occurring while attaining elite sporting expertise (Côté, Baker, & Abernathy, 2007). An efficient model of talent development has to limit the potential costs of sport expertise while maximising an individuals potential (Côté, Baker, & Abernathy, 2007). DMSP has three pathways to allow attainment of elite level performance: Recreational Participation through Sampling, Elite Performance through Sampling and finally Elite Performance through Early Specialisation (Côté, Baker, & Abernathy, 2007).

Côté, Baker and Abernathy (2007) describe the first of three pathways as Recreational Participation, which is a mix of deliberate play and practice with overall benefits for both health and enjoyment being achieved through sport participation. Elite Performance through Sampling advocates for a similar beginning as Recreational Performance, where sampling should occur between the ages of 6-12, but from the age of 13 athletes should specialise in fewer sports. The ages of 13-15 will allow youth athletes to focus on fewer sports with a variation in deliberate play and practice. By the age of 16 youth athletes are ready to commit to a singular sport and should devote significant amount of deliberate practice time towards attaining elite expertise. In attaining elite performance in this manner athletes have better physical and mental experiences. The final pathway, Elite Performance through Early Specialisation, is akin to the standard model of development as previously described.

1.2.6.4. Abbott and Collins Model

Abbott *et al.* (2005) based their multidiscipline model on the initial work done of Bloom (1985). The four macro stages are: Initiation, Development, Mastery and the Perfection stage. Abbott *et al.* (2005) criticised past talent development models for being too static, utilising mono-disciplinary approaches and not focusing on the development of an athlete. An inclusive, collective approach is heavily advocated for with the term talent identification considered a misnomer (Abbott *et al.,* 2005). Talent development more accurately reflects how elite athletic performance should be achieved as the ability to successfully identify talented athletes at a young age is fraught with difficulties, as outlined in section 1.2.4 (Abbott *et al.,* 2005).

Abbott *et al.* (2005) argue that in order to successfully transition between each macro stage, micro and meso pathways are present. Overcoming potential obstacles is dependent on a youth athlete's psychological behaviour. Possessing the desired psychological temperament allows for appropriate goal-settings to be implemented and introspective, realistic performance evaluation to be conducted. Subsequently, athletes which display such virtues are better equipped to navigate obstacles and continue their development towards elite performance. The model does acknowledge its limitations as a player may possess the required psychological ability but not have the necessary physical or technical ability. These natural, individual constraints are what makes talent development so difficult.

1.2.6.5. Long Term Athletic Development Model

Balyi and Hamilton (2004) attempted to clarify the focus of child progression in their model of Long Term Athletic Development (LTAD). This model defines the different stages of development a youth athlete will experience and how to best optimise physical abilities as well as technical and psychological characteristics.

Balyi and Hamilton (2004) describe how certain ages are marked by identifiable changes. Each of these components, referred to as the 5 S's (stamina, strength, speed, skill and suppleness), along with personality and cognition can be improved within critical windows. Individually tailored training programs can be created for short and long term goals to be achieved, as well as allowing adequate exposure to competition and optimal recovery programs.

The 6 stages of LTAD are: 1) FUNdamentals stage, 2) Learning to Train, 3) Training to Train, 4) Training to Compete, 5) Training to Win and 6) Retirement/ Retainment.

Athletic development begins with the action kids phase (0-5 years old) whereby simple movement patterns are taught. Sport specific skills are not introduced due to the age of the children. The aim is to allow participation in a number of movements and activities which build basic motor functions needed for further development.

The second phase is the 'FUNdamentals', age range between 6-9 years old for males and 6-8 for females, with the goal to promote fundamental motor functions and coordination. Children should experience physical activity in a creative manner facilitating and encouraging future participation. The goal should also be to introduce different sports, each utilising varied fundamental movement patterns and capacities (Ford, De Ste Croix, Lloyd, Meyers, Moosavi, Oliver, Till, & Williams, 2011).

The third phase is 'Learning to Train', which incorporates more skill related aspects of a sport along with the introduction of cognitive and emotional development (Balyi & Hamilton, 2004). Physical capabilities are still improved but transitioning the basic motor functions into more sports specific scenarios (Ford *et al.*, 2011). This is a vital age for development as children aged between 9-12 are at a key stage to acquire the sports specific skills (Balyi & Hamilton, 2004).

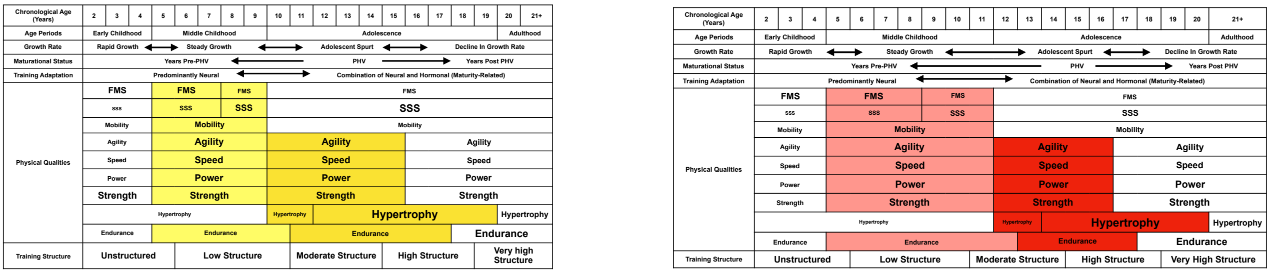
'Training to Train' is the fourth phase of a child's athletic development according to this model. This occurs during the first growth spurt once an athlete experiences puberty, usually between the ages of 12-16 (Balyi & Hamilton, 2004). Literature pinpoints this time as essential for training aerobic capacity (Viru, Loko, Harro, Volver, Laaneots, & Viru, 1999; Naughton, Farpour-Lambert, Carlson, Bradney, & Van Praagh, 2000; Philippaerts, Vaeyens, Janssens, Van Renterghem, Matthys, Craen, Bourgois, Vrijens, Beunen, & Malina, 2006). Improving this domain through low intensity but high volume work will set a base for future athletic performance (Balyi & Hamilton, 2004). Attention should be directed towards individual, team and sport related skill training (Balyi & Hamilton, 2004). Furthermore, as players age the importance of strength training basics and mental preparation techniques are required (Philippaerts *et al.*, 2006).

At the ages of 16-18, strength and power work is introduced allowing for optimal physical development (Balyi & Hamilton, 2004). Improvement in sports specific skills are maintained but competitive experience is the target (Lloyd, Oliver, Faigenbaum, Howard *et al.*, 2015b). Goal setting and adjustments, particularly with unsatisfactory performances, should be made as this phase is concerned with training to compete (Balyi & Hamilton, 2004). The individual should be equipped with the physical, technical and cognitive skills or abilities necessary for a chosen sport (Vaeyens *et al.,* 2008).

Stage six is the final stage of an athletes youth development, which is titled 'Training to Win', and is for individuals 18 and over. This refinement period ensures athletes are sufficiently ready for elite level competition (Balyi & Hamilton, 2004). The groundwork from the previous stages has set up the athlete to be ready for elite or professional level sport, with minor continuous adaptations required as the athlete progresses towards their age of retirement. A strong critique of the long term athletic development model is the lack of empirical evidence for sensitive or critical windows of training (Bailey *et al*., 2010). Further evidence as to why such windows are not considered critical will be presented later, as they are referred to as accelerated windows of development. Additional criticism for the lack of maturity testing is also present as LTAD only uses chronological age (Lloyd & Oliver, 2012). As with previous models, the LTAD is a largely theoretical construct which may underpin future research but so far does not have any empirical evidence to support its claim (Ford *et al*., 2011; Bailey & Collins, 2013; Lloyd *et al.,* 2015a). Finally, the LTAD advocates for the 10,000 hour rule of deliberate practice to be present which literature has shown not to be required for successful athlete development (Lloyd *et al.,* 2015a)

1.2.6.6. Youth Physical Development Model

The Youth Physical Development (YPD) model takes the principle ideas from LTAD, specific areas of development at appropriate times, but integrates current research into physical and technical progression while integrating maturity testing Lloyd and Oliver (2012). As discussed in section 1.2.8.4. there are limitations to the LTAD model which Lloyd and Oliver (2012), propose solutions to effectively develop youth



athletes. This information is neatly summed up in Figure 2 below.

A B

Figure 2. Adapted Youth Physical Development model (Lloyd & Oliver, 2012) for females (A) and males (B).

Larger font size indicates greater importance, light colouring is preadolescent adaption periods while dark represents adolescent adaptation periods. FMS is fundamental movement skills; PHV is Peak Height velocity; SSS is sports specific skills.

This model forms as a reference point for the thesis whereby individual maturation is accounted for and its effects on a variety of anthropometric, physical and physiological components can be investigated.

1.2.6.7. Summary of Multidiscipline Models

A holistic, multidiscipline model, utilising maturity age testing, incorporated within a longitudinal and collectivist approach is a consistent theme in these models (Gagné, 2000; Abbott *et al.,* 2005; Côté, Baker, & Abernathy, 2007; Vaeyens *et al.,* 2008; Bailey *et al.*, 2010; Lloyd & Oliver, 2012; Pankhurst & Collins, 2013; Lloyd *et al.,* 2015a; Rees, Hardy, Güllich, Abernethy, Côté, Woodman, Montgomery, Laing, & Warr, 2016). Talent development is dynamic and non-linear where young players grow and learn at varying individual rates and tempos (Lloyd *et al.,* 2015a; Rees *et al.,* 2016). Care has to be taken to reduce the mental and physical toll placed upon young athletes and this can be achieved by alleviating the pressures usually associated with the standard model (Bailey *et al.*, 2010). Constant reevaluation to assess and address any potential issues will mitigate the chances of missing talented youth athletes (Bailey *et al.*, 2010; Lloyd *et al.,* 2015a). Each model presented utilises a variety of techniques to develop talent and have their own positives and negatives (Gagné, 2000; Abbott *et al.,* 2005; Côté, Baker, & Abernathy, 2007; Vaeyens *et al.,* 2008; Bailey *et al.*, 2010; Lloyd & Oliver, 2012; Lloyd *et al.,* 2015a; Rees *et al.,* 2016).

Models advocate the sampling of a variety of sports at a young age, to allow development of a wide range of skills which are not specific to one particular sport (Côté, Baker, & Abernathy, 2007; Vaeyens *et al.,* 2008). The transfer effect of certain fundamental sport specific skills to another can be extremely beneficial (Pankhurst & Collins, 2013). Furthermore, this does not prevent athletes from specialising in a chosen sport much later in their developmental timeline and are still able to achieve elite success (Côté, Baker, & Abernathy, 2007).

These models should however not be seen in isolation but rather linked to the development process that youth undergo, acknowledging the complexity of this process will allow better utilisation of multidiscipline and holistic models. Ultimately this will create a clearer understanding of child athletic development and how to approach each individual athlete in the most efficient manner.

1.2.7. Youth Development

1.2.7.1. General Childhood Development

As a child ages they will undergo a series of anatomical, neurological and hormonal changes each impacting physical, anthropometric and physiological characteristics and capabilities (Viru *et al.,* 1999). Of great interest is the impact of puberty on an individual and its relation to chronological age in terms of athletic development (Viru *et al.,* 1999; Naughton *et al*., 2000; Bailey *et al.*, 2010; Towlson, Scott, Bray, Barrett, & Weston, 2018). Consideration will also be given to both positive and negative influences on the pubertal process.

A period of accelerated growth is evident between the ages of 0 - 6 years old, stable growth between 7 - 11 years of age with another accelerated growth period at 12 - 16 years old, with growth gently plateauing at around the age of 20 years old (Rogol, Roemmich, & Clark, 2002). This creates the well established 'S-shaped' pattern of general growth that individuals experience (Viru *et al.,* 1999). Of particular importance is the rapid, accelerated growth periods and how these can be utilised, as 'windows of trainability', to further improve athletic performance in young athletes (Balyi & Hamilton, 2004, Bailey *et al*., 2010). The effectiveness of such windows has been contested and a review of the literature will give greater indication as to why this theory is disputed (Lloyd & Oliver, 2012).

A child's youth development is fundamentally impacted by their natural growth rate and the rate, timing and tempo of their maturational process (Viru *et al.,* 1999; Rogol, Roemmich, & Clark, 2002; Bailey *et al.,* 2010). Development is inherently genetic driven, but environmental factors have an influence on the individual (Rogol, Roemmich, & Clark, 2002). There are numerous complex interactions which can influence an individuals growth rate (Naughton *et al.,* 2000; Bailey *et al.,* 2010).

Investigating research on youth maturity and its impact on physical development will allow a more comprehensive understanding as to how children develop athletically and possible implications from the pubertal process.

1.2.7.2. Anatomical, Muscular, Hormonal and Neurological Development

<u>Prepubertal Characteristics</u>

Patterns concerning prepubertal growth heights have been established with normal ranges being established depending on initial height (Rogol, Roemmich & Clark, 2002). Growth hormone (GH) and insulin-like growth factor (IGF)-1 are secreted in small doses with similar levels for males and females (Naughton *et al.,* 2000; Rogol, Roemmich, & Clark, 2002). IGF-1 is responsible for the maintenance and growth of muscle tissue, connective tissue, cartilage, bone growth by instigating cartilage development and finally collagen production (Naughton *et al.,* 2000; Rogol, Roemmich, & Clark, 2002). Nutrition is a key requisite for growth hormone stimulated IGF-1 production and can be disrupted (Rogol, Roemmich, & Clark, 2002).

Pubertal Characteristics

Biological maturity is referred to as the 'qualitative system changes, both structural and functional, in the body's progress toward maturity' (Meylan *et al.,* 2010). Puberty traditionally occurs at the skeletal age of 11 years for females and 13 years for males and produces distinct differences for each sex (Viru *et al.,* 1999; Naughton *et al.,* 2000; Rogol, Roemmich, & Clark, 2002). The rate of maturity will differ between individuals in terms of timing, tempo and duration (Philippaerts *et al*., 2006; Bailey *et al.,* 2010; Meylan *et al*., 2010). Maturity can be influenced by a variety of factors namely: ethnicity (Rogol, Roemmich, & Clark, 2002), socioeconomic status (Rogol, Roemmich, & Clark, 2002; Rees *et al*., 2016), nutritional intake (Rogol, Roemmich, & Clark, 2002), physical activity (Sherar *et al*., 2010) or injuries (van der Sluis, Elferink-Gemser, Coelho-e-Silva, Nijboer, Brink, & Visscher, 2014).

Periods of accelerated growth are brought forward by changes in the endocrine system and the resultant effects it has on the human body (Viru *et al.,* 1999; Bailey *et al.,* 2010). Sexual maturation stimulates the release of testosterone in males and estradiol in females, in conjunction with adrenal androgens (Rogol, Roemmich & Clark, 2002). Hormonal changes during puberty result in the release of growth hormone, steroid sex hormones and insulin-like growth factors all of which dictate bone and muscle development in addition to fat storage (Rogol, Roemmich, & Clark, 2002; Bailey *et al.,* 2010).

The most obvious component to identify human growth is the increase in stature. Stature increase is non-uniform throughout its development with the S-shaped growth pattern evident (Rogol, Roemmich, & Clark, 2002). A slowing of growth occurs just before the important pubertal spurt, otherwise known as peak height velocity (PHV) (Rogol, Roemmich, & Clark, 2002). PHV is the extended growth spurt adolescents experience during puberty (van der Sluis *et al.,* 2014). The utilisation of PHV testing has allowed the effects of puberty to be taken into account in a non-invasive manner which is comparable to the different stages of the Tanner pubertal development chart (Rogol, Roemmich, & Clark, 2002). The Tanner scale describes the various changes an individual experiences during puberty relating to their pubic and genital development (Marshall & Tanner, 1969). The use of an examination by a medical professional to discern the stage of puberty is utilised. The Tanner method has been found to show good links between each stage and increases in physical ability (Meylan *et al.,* 2010). There is some concern over the reliability of the method as wells as the possible intrusiveness of how it is conducted (Meylan *et al.,* 2010).

According to Marshall and Tanner (1969) females grow at an average PHV of nine cm a year at 12 years old, while males grow at 10.3cm a year at 14 years of age. Males attain a greater total height gain of 28cm compared to 25cm (Marshall & Tanner, 1970) and this is attributed to longer prepubertal growth as well as an increase in height during the peak height velocity phase (Naughton *et al.,* 2000; Rogol, Roemmich, & Clark, 2002).

In addition to stature increases, peak weight velocity occurs roughly 12-18 months after PHV age (Rogol, Roemmich, & Clark, 2002; Lloyd & Oliver, 2012). Males gain on average nine kg a year from the age of 14, with females averaging 8.3 kg but this increase starts a few months after PHV has been experienced (Rogol, Roemmich, & Clark, 2002). This is an important time for youth athletes as they gain the mass needed for future muscle growth (Rogol, Roemmich, & Clark, 2002). Any factors which may influence weight increase - such as poor nutrition or low socioeconomic status - will negatively impact future athletic development (Viru *et al.,* 1999; Rogol, Roemmich, & Clark, 2002).

Changes in body composition are more pronounced between males and females during puberty, especially with the distribution of fat storage and the increase in fat free mass (Naughton *et al.,* 2000; Rogol, Roemmich, & Clark, 2002). Studies have found a significant increase in lean muscle mass as individuals undergo pubertal maturation (Viru *et al.,* 1999). Males have comparatively greater levels of fat free mass and retain less fat throughout puberty (Naughton *et al.,* 2000; Rogol, Roemmich, & Clark, 2002). An increase in bone mineral content and muscle development results in increased strength capabilities for youth male individuals (Rogol, Roemmich, & Clark, 2002).

Pubertal muscle and bone development cause increases in various limb lengths allowing for greater, and more efficient mechanical, physiological and physical actions to occur (Bailey *et al.,* 2010). Reduced energy expenditure, increased force generation, as well as load distribution in bones from greater mineral deposits, are all examples of potential facilitators of increased athletic capacity (Viru *et al.*, 1999; Naughton *et al.,* 2000).

Neurological development will occur all along the maturational process which will influence skill acquisition and physical competence in terms of fine and gross motor skills (Bailey *et al.,* 2010). Varied periods of growth are also associated with neurological development, much like anatomical and muscular development (Bailey *et al.,* 2010). Each period of rapid development in neurological growth has been identified with increases in certain motor coordination and skills (Viru *et al.*, 1999; Bailey *et al.,* 2010). Research has detailed how peak neurological development occurs at 15 - 24 months, 6 - 8 years of age, 10 - 12 years and then finally at 18 years of age (Rabinowicz, 1986; Thatcher, Walker, & Giudice, 1987). These ages coincide or predate anatomical growth periods indicating that overall motor performance may limited by neurological development (Viru *et al.,* 1999).

1.2.7.3. General Fitness Component Development

As found in the critique of LTAD, a lack of evidence can be found on supposed windows of trainability, which may be inherent as an individual undergoes the developmental maturational process (Lloyd *et al.,* 2015a). Therefore, context is provided by describing the development of aerobic and anaerobic capacities with the impact of age and maturity related differences. Once the general classification of these capacities is outlined a more football specific outline can be explained.

Table 1: Adapted Viru *et al.* (1999) table highlighting the longitudinal and cross-sectional studies on prepubescent and pubescent athletes.

	Males		Females	
	Pre-Pubescent Spurt	Pubescent Spurt	Pre-Pubescent Spurt	Pubescent Spurt
Aerobic Performance				
Longitudinal	5-9	12-14/14-16	5-9	12-14/14-16
Cross-sectional Studies	-	12-15	7-10	11-13/13-16
Anaerobic Performance				
Strength				
Longitudinal	5-9	13-16	5-9	10-15
Cross-sectional Studies	-	13-15	-	11-15
Speed				
Longitudinal	5-9	12-14	5-9	-
Cross-sectional Studies	7-11	13-16	6-9	13-16
Power				
Longitudinal	5-9	12-16	5-9	9-13
Cross-sectional Studies	7-11	13-16	6-9	12-12

As Table 1, highlights there are different maturation points for various athletic abilities for either males and females. The initial pre-pubescent spurt is similar for both males and females at an age of 5-9, and this has been widely used and corroborated (Viru *et al*., 1999). Differences occur at the puberty spurt with females generally maturing earlier and certain motor components being affected at a younger age, such as aerobic performance.

This is not to suggest a preset window of trainability is present but rather the natural puberty related changes an individual experiences will produce increased outcomes in certain motor capacities. It is important to note these motor component changes, as well as the intra-individual variability present, along with the causes and potential ramifications of each new development.

Therefore, a summation of how each physical component develops along with the impact of puberty, particularly during PHV, will be discussed. The areas covered will be first split into broad categories, namely general aerobic capacity and anaerobic capacity, which is further subdivided into strength, power and speed components.

1.2.7.4. Aerobic Capacity

Aerobic fitness is a required component for different sporting and exercise activities, with performance being defined as the ability to deliver oxygen to the muscles and utilise energy through aerobic metabolism mechanisms (Armstrong & Barker, 2011). Aerobic ability is specifically regulated by the capacity of the individual to synthesis adenosine triphosphate, and the efficiency of the central and peripheral cardiovascular system (Bailey *et al.,* 2010). Additional factors include muscular function and composition, cellular transfer ability, anthropometric and body composition, and metabolic capacity (Bailey *et al.,* 2010; Armstrong & Barker, 2011).

A growing child will experience an increase in their aerobic ability due to the development of their cardiac, as well as the muscular, anatomical, neurological and hormonal systems occur (Viru *et al*.,1999; Naughton *et al.,* 2000; Bailey *et al.,* 2010; Ford *et al*., 2011). Maximal oxygen uptake increases linearly throughout childhood when accounting for body weight (Viru *et al*.,1999). Peak $\dot{V}O_2$ can be increased by between 80-150% for youth athletes between the age of 8 to 18 years old (Armstrong & Barker, 2011). As body mass increases with age, the ratio of $\dot{V}O_2$ max to body weight for males remains between 48-50ml.kg^{-1}.min^{-1}, however this is for untrained individuals, with females suffering a decline in their values, from 45 ml.kg^{-1}.min^{-1} to 35ml.kg^{-1}.min^{-1} (Armstrong & Barker, 2011).

Maturation is therefore a significant variable on an individual's aerobic fitness capacity (Viru *et al*.,1999; Naughton *et al.,* 2000). Improvements can be attributed too many factors such as genetic or environmental and individual exposures and training loads (Baquet, Van Praagh & Berthoin, 2003; Armstrong & Barker, 2011). The Fick equation calculates $\dot{V}O_2$ as the combination of cardiac output and arterio-venous oxygen difference (Armstrong & Barker, 2011). Research has shown limited differences occur in arteriovenous difference between trained and untrained youth athletes, thus any positive changes are attributed to increases in cardiac output (Armstrong & Barker, 2011). Additional improvements in energy expenditure during locomotion can be attributed to lower limb growth, blood lactate thresholds and oxygen uptake ability, in addition to growth in heart size and heart strength (Viru *et al*.,1999; Naughton *et al.,* 2000; Baquet *et al.,* 2003; Bailey *et al.,* 2010; Ford *et al*., 2011). As the muscular system develops increased mass is present to allow for greater vascularisation, additional muscle mass also allows increased strength and power reducing the effects of fatigue (Bailey *et al.,* 2010). Increased neurological development would allow greater motor coordination and better recruitment of muscle fibres (Viru *et al*.,1999; Bailey *et al.,* 2010).

Therefore, the maturation of an individual from child to adolescent to adult, greatly impacts their aerobic fitness capacity (Ford *et al.,* 2011). Positive developments in these capacities will influence their talent level and help to improve performance (Armstrong & Barker, 2011). The specific mechanics of how and why this occurs is beyond the scope of the current thesis but the important takeaway is the level of trainability throughout the maturation phase (Naughton *et al.,* 2000).

1.2.7.5. Anaerobic Capacity

Strength, Speed & Power

Anaerobic exercise involves the utilisation of energy in the absence of oxygen (Bailey *et al.,* 2010). Different mechanisms are used with the outcomes varying according to the intensity and explosiveness of actions which will vary over distance and time (Bailey *et al.,* 2010; Ford *et al.,* 2011). The utilisation of different speed, strength and power actions is necessary in a large number of sports in order to compete effectively (Harries, Luban & Callister, 2012). Strength, power, acceleration, speed, and agility are the main anaerobic actions and will be discussed accordingly (Reilly *et al.,* 2000; Pichardo *et al.,* 2018).

Strength is the amount of force an individual can produce in one maximal, voluntary contraction (Turner, Walker, Stembridge, Coneyworth, Reed, Birdsey, Barter, & Moody, 2011; Granacher, Lesinski, Büsch, Muehlbauer, Prieske, Puta, Golhofer, & Behm, 2016; Moran, Sandercock, Ramirez-Campillo, Meylan, Collison & Parry, 2016). Strength is muscle dependent and is largely modifiable for individual athletes (Granacher *et al.,* 2016). Strength is required to complete a variety of actions and movements, these actions include: kicking, jumping, throwing, running and changing direction (Turner *et al*., 2011; Moran *et al.*, 2016).

Power is work done in a certain time period, with work being defined as force multiplied by distance, and optimal power development requiring high levels of strength and force production (Granacher *et al.,* 2016). Power is described as “the maximal, instantaneous, singular movement performed to produce velocity at either take off, release or impact” (Meylan, Cronin, Oliver, Hughes & Manson, 2014, p. 1242). A linear relationship has been shown in studies between one repetition maximal tests for strength and tests for power including vertical jump, countermovement jump or broad jump (Turner *et al*., 2011). Force production is dependent on the characteristics of an individual’s muscle, both size, lever type and fibre characteristics (Viru *et al*.,1999).

Turner *et al.* (2011) describe speed as having 3 components: acceleration, attaining peak speed and maintenance of peak speed. An individual has to have the required power to accelerate quickly over short distances, the anaerobic and power capability to get up to full speed and then the ability to complete multiple sprints in short periods of times (Turner *et al.,* 2011; Oliver, Lloyd & Rumpf, 2013). Speed is often a critical characteristic required in a multitude of sports which has been shown to positively affect a match result (Oliver, Lloyd & Rumpf, 2013).

Agility utilises acceleration, change of direction, top speed attainment and deceleration mechanisms in order to be successful (Sheppard & Young, 2006). A wide variety of definitions for agility are available with consensus hinging on several variables (Sheppard & Young, 2006). The traditional definition is the ability to change direction rapidly (Sheppard & Young, 2006). Baker (1999) used quickness as a clarifying statement whereby agility is a “multi-planar or multidirectional skill which combines acceleration, explosiveness and reactiveness” (Sheppard & Young, 2006,

p. 3). Thus agility is defined as “a rapid whole-body movement with change of velocity or direction in response to a stimulus” (Sheppard & Young, 2006, p. 4).

The maturational developments of the hormonal, muscular, anthropometric and neurological systems create positive changes in an athlete’s anaerobic performance (Viru *et al*.,1999). Possible performance increases in anaerobic domains could be attributed to an increase in muscle mass and cross sectional area (Viru *et al*.,1999; Ford *et al.,* 2011; Lloyd & Oliver, 2012), limb growth (Viru *et al*., 1999; Moran *et al.*, 2016), improved biomechanical action (Bailey *et al.,* 2010), neurological improvement (Oliver, Lloyd & Rumpf, 2013), hormonal increase such as IGF-1 (Naughton *et al*., 2000; Lloyd & Oliver, 2012), testosterone (Ford *et al.,* 2011; Lloyd & Oliver, 2012) or human growth (Viru *et al*., 1999; Naughton *et al*., 2000); all combining to define the performance spurt commonly associated with PHV.

Youth athletes closer to their PHV have an advantage whereby they maintain extensive increases in agility, power, strength and sprint speed when compared to those who have not experienced their PHV (Philippaerts *et al.,* 2006; Lloyd & Oliver, 2012). Depending on the type of test, training status of population tested and age of population results will vary but what is apparent is the increase in performance level as an individual ages (Lloyd & Oliver, 2012). PHV has been found to influence the number of injuries a player will experience between the ages of 12-16 (van Der Sluis *et al*., 2014).

<u>Increases in strength around PHV and its development</u>

Strength development curves will mimic human growth curve as strength gains increase with age, particularly around PHV. Strength is the basis for future power and muscular endurance performance by complimenting natural athletic growth (Granacher *et al.,* 2016). The multi-faceted and complex nature of strength development is dependent on muscular, neural and mechanical components (Ford *et al.,* 2011; De Ste Croix, Armstrong, Welsman, & Sharpe, 2002). Adequate strength allows the demands of training and competition to be met and surpassed (Granacher *et al.,* 2016). Without appropriate strength training and correct movements learnt, neurological and muscle development is reduced and this may have negative impacts on future development (Lloyd & Oliver, 2012).

Average strength levels will vary between populations (Granacher *et al.,* 2016). Steady increases in strength are apparent up until the age of 14 for both males and females (Ford *et al.,* 2011). After this age, a spurt is noticeable in males while females will experience a plateau in their strength capabilities (Viru *et al.,* 1999; Ford *et al.,* 2011). Again, this age is an approximation with it being dependent on maturity status, specific muscle group and muscle action (Ford *et al.,* 2011; Moran *et al.*, 2016). Ford *et al.* (2011) summarise the longitudinal studies which have adequately accounted for maturation when investigating strength development. Increased stature is an important variable for strength improvement, particularly after the growth spurt (Wood, Dixon, Grant & Armstrong, 2006; Ford *et al.,* 2011).

A major study consideration has been the impact of resistance training on strength development for pre-pubertal and pubertal individuals (Naughton *et al.,* 2000; Behringer, vom Heide, & Yue, 2010; Bergeron *et al.,* 2015; Granacher *et al.,* 2016; Moran *et al.,* 2016; Behm, Young, Whitten, Reid, Quigley, Low, Li, Lima, Hodgson, Chaouachi, Prieske, & Granacher, 2017). Resistance training can have a positive impact on strength development in youth athletes which has further extended effects on balance and coordination, power, agility, speed and muscular endurance (Naughton *et al.,* 2000; Bergeron *et* al., 2015; Lloyd & Oliver, 2012; Granacher *et al.,* 2016; Moran *et al.,* 2016; Behm *et al*., 2017). However, the age of initiation is important as limited benefits have been found for pre-pubertal individuals due to the lack of androgens and various strength building hormones (Naughton *et al.,* 2000; Moran *et al.,* 2016). Strength training for individuals experiencing puberty, particular around PHV, has been shown to be highly beneficial (Naughton *et al.,* 2000; Behringer, vom Heide, & Yue, 2010; Harries, Luban & Callister, 2012; Bergeron *et* al., 2015; Granacher *et al.,* 2016; Moran *et al.,* 2016; Behm *et al*., 2017; Pichardo *et al.,* 2018).

Increases in power around PHV and its development

Possessing appropriate strength levels and movement patterns, enhanced by greater neurological control, allows for increased power development which is an essential characteristic for youth athletes (Granacher *et al.,* 2016; Moran *et al.,* 2016; Behm *et al*., 2017). A first improvement can be seen in pre-pubescent athletes between the ages of 5 and 10 years, while a second is noticeable at the onset of puberty (Ford *et al.,* 2011). The increase in power occurs approximately one and half years before an individual experiences PHV, and this is maintained up until one year past PHV, between the ages of 12 to 15 years of age (Ford *et al.,* 2011; Meylan *et al.,* 2014,). Studies investigating the trainability of power capabilities in youth athletes have found the aforementioned pubertal changes occur mid PHV, with little effect pre PHV (Meylan *et al.,* 2014). In terms of power output, studies have found an increase in peak power of 102% between the ages of 12-17 (Meylan *et al.,* 2014).

The associated changes brought about by puberty are the driving factor for increased power (Ford *et al.,* 2011). Initial increases in power are stimulated by PHV but maximal power is more observable during the peak weight velocity phase of an individuals growth (Ford *et al.,* 2011). Sex-related differences in power are observable in terms of power output due to the increased stature, reduction in body fat and increase in muscle (Temfemo, Hugues, Chardon, Mandengue & Ahmaidi, 2009). Possible explanations for the increase in power output have been listed as the following: increased muscle cross section (Ford *et al.,* 2011), neurological improvement (Viru *et al.,* 1999; Van Praagh & Doré, 2002), fibre type composition (Meylan *et al.,* 2014) and prior training experience in addition to hormonal and physical changes present during puberty (Ford *et al.,* 2011; Meylan *et al.,* 2014).

Increases in speed around PHV and its development

Speed development mimics a similar pattern found in strength and power profiles with none being a linear process (Oliver, Lloyd & Rumpf, 2013). This being an increase between the ages of five and ten years old, followed by a greater improvement at puberty (Ford *et al.,* 2011, Viru *et al.,* 1999). Females experience an earlier peak increase, due to their early onset of puberty, but noticeably lack the same level of development when compared to males (Ford *et al.,* 2011). Again, the changes brought on by puberty markedly increase an individuals athletic capacity (Oliver, Lloyd & Rumpf, 2013). The adaptations of the biomechanical, physiological, hormonal, neurological and chemical systems all contribute towards speed development in a complex and unpredictable manner (Ford *et al.,* 2011). Therefore, it is difficult to distinguish one capability as being responsible for the improvement in speed for youth athletes.

An initial increase in neurological control may be responsible for improvement for five and ten years olds (Ford *et al.,* 2011). At the age of seven years old children perfect their adult gait through the aid of increased central nervous system development (Oliver, Lloyd & Rumpf, 2013). Cowley, Hamlin, Grimley, Hargreaves and Price (2010) indicate between 5-25% of 8-10 year olds, across differing populations and nationalities, are fully proficient in their sprinting technique.

The onset of puberty, and again most importantly PHV, creates favourable changes such as increase in muscle tissue stiffness (Ford *et al.,* 2011). The first possible cause is more muscle and tendon architecture whereby there is an increase in muscle-tendon junction size (Ford *et al.,* 2011), increased firing rates (Whitall, 2003), twitch times (Lin, Brown & Walsh, 1997) and co-activation (Lambertz, Mora, Grosset & Perot, 2003). Additional increases can also be attributed to an increase in hypertrophy of fast twitch fibres brought on by hormonal release predominantly in male athletes (Oliver, Lloyd & Rumpf, 2013).

<u>Increases in agility around PHV and its development</u>

Exceptional agility levels are required to compete in elite level sporting environments and are often vital to the outcome of a match, particularly in football (Turner *et al.,* 2011; Lloyd, Read, Oliver, Meyers & Nimphius, 2013). However, a lack of research focusing on the development of agility in youth athletes has been conducted (Lloyd *et al.,* 2013). As defined earlier, agility requires change of direction, acceleration, straight line speed, lower limb strength and power as well as various cognitive components (Sheppard & Young, 2006; Lloyd *et al.,* 2013).

As with the previous anaerobic capacities change of direction components will develop in a non-linear rate (Lloyd *et al.,* 2013). Thus, the causation mechanisms will be very similar to power, speed and strength development. Initial spurt in preadolescence is attributable to increased nervous system development along with better motor skill coordination (Viru *et al.,* 1999; Lloyd *et al.,* 2013). Better agility performance during puberty will be from a combination of hormonal release such as testosterone, growth hormone and IGF-1 (Viru *et al.,* 1999). An increased muscle cross sectional area, greater neural development and increased fibre type development resulting in greater force production is the main driving factor behind improved performance (Malina, Bouchard & Bar-Or, 2004; Tonson, Ratel, Le Fur, Cozzone & Bendahan, 2008; Lloyd *et al.,* 2013).

1.2.8. Football Activity Profiles

1.2.8.1. Football Specific Model

Williams and Reilly (2000) created a football specific model which identifies all the major components required to play the sport. Football is a multi-component sport with successful development requiring the following attributes or abilities: certain anthropometric attributes, physical and physiological abilities, perceptual-cognitive skills, specific psychological predictors as well as environmental predictors (Williams & Reilly, 2000). These authors argue no component should be considered more important and each athlete must be examined on their strengths and weaknesses rather than prioritising certain attributes. The compensation phenomenon details how an individual may overcome a deficit in one aspect of their abilities by excelling in another (Vaeyens *et al.,* 2008; Woods, Raynor, Bruce, McDonald, & Roberston,2016). An example would be a smaller, less physically gifted player developing their technical skills to compensate for a lack of speed (Williams & Reilly, 2000).

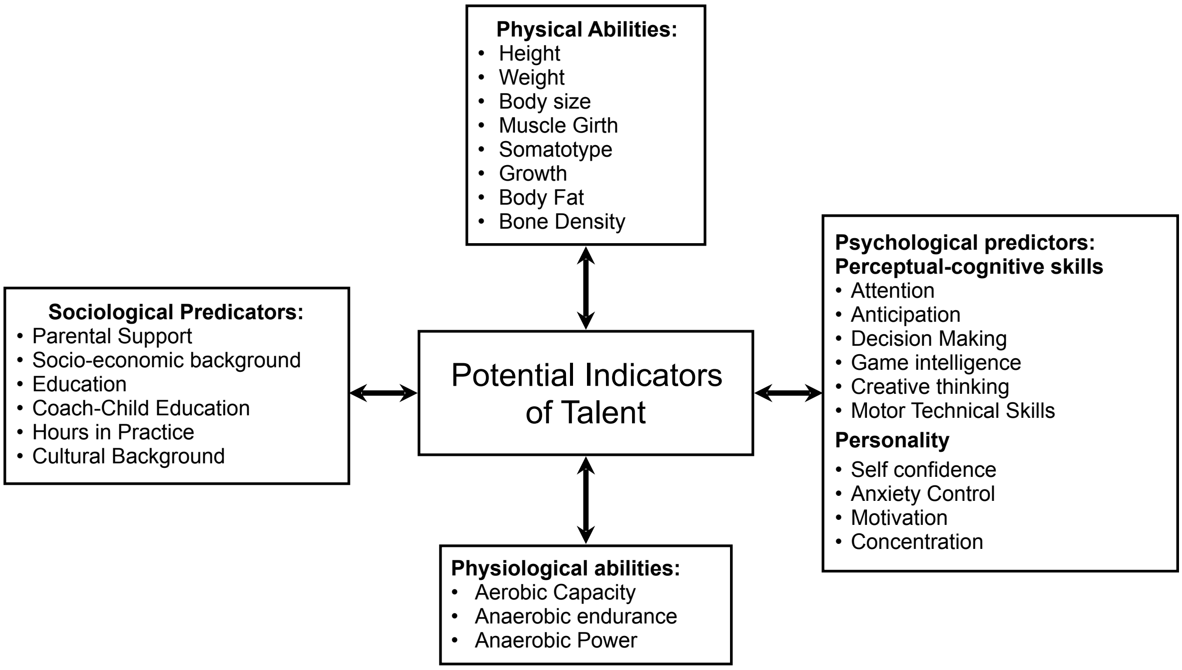


Figure 3: Potential Predictors of Talent in Soccer (adapted from Williams & Reilly, 2000)

The sections below will seek to identify the requirements to compete at elite level football along with the developmental process of youth individuals. In first identifying the elite requirements we can establish baseline results which a youth player would have to attain. These may vary according to country and league so a focus on elite league research among different nations, as well as South African footballing research, will be considered.

1.2.8.2. Requirements of Football

1.2.8.2.1. Physical and Physiological Team Profile

Football is an intermittent sport which mixes a variety of running speeds (Buchheit, Mendez-Villanueva, Simon, & Bourdon, 2010), changes of directions (Lloyd *et al*., 2013), accelerations and decelerations (Comfort, Stewart, Bloom, & Clarkson, 2014), cardiovascular capabilities (Castagna, Manzi, Impellizzeri, Weston, Carlos, & Alvarez, 2010) and different technical actions (Ali, 2007). The number of different movements a player performs in a game is described as the activity profile (Bangsbo, Mohr & Krustrap, 2006). Initial research by Reilly (1994) found outfield players will run on average between 8-11 kilometres a match. This is covered by performing 1000 different activities equating to a change in activity every six seconds, although modern studies have found increase to 1400 (Reilly, 1994; Mohr, Krustrup, & Bangsbo, 2003; Bangsbo, Mohr & Krustrap, 2006). The distance covered in a match is usually considered the barometer of activity level but it is worth noting other actions involved, such as jumping to contest a ball, kicking or sideways movements, are not expressly noted and this may have an impact on overall energy expenditure (Reilly, 1994; Bangsbo, Mohr & Krustrap, 2006).

The activity profile for elite soccer players has shifted to include a greater total distance covered, among other increases (Mohr, Krustrup, & Bangsbo, 2003). In doing so, it has placed a greater demand on youth athletes in terms of the physiological characteristics needed to succeed at an elite level (Burgess & Naughton, 2010). The increase in total distance covered in an elite level game has been shown to be between 10-11kms on average, with a high of 14kms (Mohr, Krustrup, & Bangsbo, 2003; Bloomfield, Polman, & O'Donoghue, 2007; Bradley, Sheldon, Wooster, Olsen, Boanas, & Krustrup, 2009). The use of technology creates a more accurate representation of total distance covered (Carling, Bloomfield, Nelsen & Reilly, 2008). Running total has only slightly increased but this measurement is more accurate and reliable (Di Salvo, Baron, Tschan, Calderon Montero, Bachl & Pigozzi, 2007; Carling *et al.,* 2008). Low, medium, high and very high intensity movements have been used although speed values have varied between studies (Mohr, Krustrup, & Bangsbo, 2003; Di Salvo *et al.*, 2007). As described by Mohr, Krustrup, and Bangsbo (2003) an elite level footballer will spend the 19.5% of the time standing, 41.8% walking, 16.7% jogging, 17.7% running (reflected as both low, backwards and moderate speed running), 2.8% high speed running and finally 1.4% sprinting.

The total amount of high intensity runs completed, as well as speed and duration of runs, have increased (Bradley *et al*., 2009). Teams which complete a greater total amount of high intensity runs, at a more frequent rate, and maintain high speed levels win more games (Mohr, Krustrup, & Bangsbo, 2003; Carling *et al*., 2008;

Bradley, Noonan, Nugent, & Scales, 2008; Bradley *et al*., 2009; Rampinini, Impellizzeri, Castagna, Coutts, & Wisløff, 2009). The speed at which a distance is covered, along with duration and number of high intensity runs, allows comparisons between different competition levels, leagues and nations (Di Salvo *et* al., 2007; Bloomfield *et al.,* 2007; Harley *et al*., 2010; Dellal *et al*., 2011). Tactical style, level of competition, age and sex are all factors which influence a teams activity profile (Mohr *et al,* 2003; Bangsbo *et al.,* 2005; Bloomfield *et al*., 2007; Bradley *et al*., 2009; Rampinini *et al.,* 2009).

1.2.8.2.2. Individual Playing Profiles

Differences in anthropometric, physical and physiological abilities are present between positions (Reilly *et al.,* 2000). Anthropometric and physical differences will occur due to the role each position has to fulfil (Reilly *et al.,* 2000). Positions described are goalkeepers, defenders, midfielders and strikers (Strauss, Ziv, & Stein, 2012).

In terms of elite level anthropometrics there are clear differences in height, weight and body fat percentage when evaluating between positions. Goalkeepers were found to be the tallest and heaviest, followed by central defenders (Gil, Ruiz, Irazusta, Gil, & Irazusta, 2007). Strikers were adjudged to be the lightest, and shortest, while midfielders tended to be closer in profile to strikers than to any defensive position (Strauss, Ziv, & Stein, 2012). Additionally, body fat percentages are in accordance with height and weight findings with players not exceeding 13% and defensive players having a greater amount than midfielders or forwards (Gil *et al*., 2007).

The total duration, level of intensity and total distance run will differ by position (Strauss, Ziv, & Stein, 2012). Goalkeepers perform the least amount of sprints and cover the least total distance (Rampinini, Bishop, Marcora, Ferrari Bravo, Sassi, & Impellizzeri, 2007). Comparisons between outfield positions often do not take goalkeeping statistics into account due to their unique role in the team (Rampinini *et al*., 2007). Central defenders produce the highest strength levels, but have decreased acceleration and speed capacity in accompaniment with a lower total distance covered (Bloomfield, Polman, & O'Donoghue, 2007; Rampinini *et al*., 2007). Midfielders, due to their tactical role, will cover the greatest distance within a match (Rampinini *et al*., 2007; Strauss, Ziv, & Stein, 2012). Strikers are expected to be faster and will complete more sprints than a defender.

1.2.8.2.3. Youth Activity Profiles & Pubertal Development

Activity profiles for youth football are substantially different to adult leagues (Harley, Barnes, Portas, Lovell, Barrett, Pual, & Weston, 2010). As mentioned previously, the difficulty arises in fully predicting the future athletic ability of an athlete (Suppiah, Low, & Chia, 2015). Many elite junior footballers are unable to make the transition to adult leagues and competitions (Abbott & Collins, 2002; Vaeyens *et al.,* 2009; Pankhurst & Collins 2013). If the selection of individuals, at an early age, does not take into account individual maturation rates then this will remain a hinderance to effective talent development (Lloyd & Oliver, 2012; Lloyd *et al*., 2015a).

The mismatch between chronological age and biological maturity can cause misconceptions of an individuals talent level to appear (Bailey *et al.,* 2010). Individuals who experience early maturation are likely to maintain an anthropometrical and physical advantage up until the age of 16, whereby early maturational advantages should subside (Philippaerts *et al*., 2006). Furthermore, the impact of relative age effects has been well documented in skewing selection of youth individuals in a variety of sports (Cobley, Baker, Wattie, & McKenna, 2009).

Relative Age Effect

The birthdate of a youth athlete is an important metric to consider as those born earlier in the school year, either January or September (depending on location in the world), have been shown to have a greater advantage during selection for youth teams (Helsen, Baker, Michiels, Schorer, Van Winckel, & Williams, 2012; Doyle & Bottomley, 2018). This is known as the relative age effect (Vaeyens *et al.,* 2008; Burgess & Naughton, 2010; Helsen *et al.,* 2012; Unnithan *et al*., 2012; Pankhurst & Collins, 2013). The meta-analysis conducted by Cobley *et al.* (2009) sought to determine the degree to which the relative age effect (RAE) has influenced both male and female youth sport. This has been consistently shown in sports such as ice hockey (Barnsley & Thompson 1988; Grondin, Deshaies, & Nault, 1984), rugby (Abernathy & Farrow, 2005), tennis (Baxter Jones, 1995) and most importantly for the current research, football (Cobley *et al.,* 2009; Delorme, Bioché & Raspuad, 2010; Helsen, van Winkle & Williams, 2005; Meylan *et al*., 2010). RAE is most prominent in sports using a one year age grouping system (i.e. Under 12's, 13s, 14s) as it produces an inherent disadvantage for those born later in the school year (Pankhurst & Collins, 2013; Li, Wang, & Pyun, 2014).

The impact of RAE in prepubescent and pubescent athletes results in older athletes having more time throughout the year to grow and adapt to their bodies, maintaining an anthropometric and physical advantage over competitors (Helsen, van Winckel, & Williams, 2005; Malina, Cumming, Kontos, Eisenmann, Ribeiro, & Aroso, 2005; Meylan *et al*., 2010). The prevailing rational of physically gifted youth athletes maintaining such advantages throughout childhood ensures the continuation of the relative age effect (Vaeyens *et al.,* 2008). The subsequent exclusion of footballers born in the last three months of the sporting calendar year causes increased difficulty when trying to attain elite sporting expertise.

Therefore, exploring the difference in football specific physical capacities from different youth populations from footballing populations will illuminate the effects of puberty on said populations.

Football Specific Development

The pubertal process produces an increase in height, and other physical or physiological characteristics (Rogol, Roemmich & Clark, 2002). The issues around sensitive windows of trainability indicate that although there are key areas to train, while missing a certain time point is not critical to youth development (Lloyd & Oliver, 2012). Differences between elite and non-elite players has been shown in basic anthropometric profiles (Le Gall, Carling, Williams, & Reilly, 2008; Buchheit & Mendez-Villanueva, 2014).

Table 2. Anthropometric results from football Specific Studies

Author and Year	Population	Playing Level	Chronological Age	Maturity Onset/Age Peak Height Velocity	Height (cm)	Weight (Kgs)	BMI	Fat Percentage
Bidaurrazaga, 2014	European (Spanish)	Elite	Year 1: Preseason(10.9 ± 0.7) End of Season(11.5 ± 0.7) Year 2: PS(12.0 ± 0.6) ES(12.7 ± 0.9) Year 3: PS(12.8 ± 0.6) ES(13.5 ± 0.6) Year 4: PS(13.7 ± 0.6) ES(14.3 ± 0.5)	N/A	Year 1: PS(144.9 ± 5.6) ES(147.3 ± 5.7) Year 2: PS(150.9 ± 6.8) ES(154.5 ± 7.0) Year 3: PS(158.3 ± 8.6) ES(162.5 ± 8.6) Year 4: PS(166.4 ± 8.1) ES(169.9 ± 7.3)	Year 1: PS(36.0 ± 4.3) ES(37.8 ± 4.4) Year 2: PS(40.8 ± 6.0) ES(43.2 ± 6.6) Year 3: PS(47.0 ± 8.0) ES(50.3 ± 8.8) Year 4: PS(54.0 ± 9.3) ES(58.1 ± 9.2)	N/A	**(Σ6 Skin-folds, mm)** Year 1: PS(46.5 ± 11.2) ES(50.2 ± 16.4) Year 2: PS(49.9 ± 16.1) ES(50.5 ± 14.0) Year 3: PS(51.1 ± 13.0) ES(51.0 ± 13.4) Year 4: PS(46.6 ± 11.6) ES(47.3 ± 12.1)
Buchheit, 2010	Middle East (Qatarian)	Elite	U13, U14, U15, U16, U17, U18	U13 (-1.7 ± 0.4) U14 (-0.7 ± 0.5) U15 (-0.1 ± 0.7) U16 (0.6 ± 0.8) U17 (1.6 ± 0.6) U18 (2.2 ± 0.4)	U13(150.0 ± 6.0) U14(159.0 ± 7.0) U15(161.0 ± 6.0) U16(163.0 ± 9.0) U17(170.0 ± 7.0) U18(171.0 ± 9.0)	U13(39.3 ± 5.1) U14(43.9 ± 5.2) U15(48.8 ± 9.8) U16(52.0 ± 7.2) U17(58.1 ± 4.7) U18(56.3 ± 7.5)	N/A	N/A
Buchheit, 2013	Middle East (Qatarian)	Elite	U14(13.2 ± 0.6) U16(15 ± 0.6) U18(16.9 ± 0.6) Pre-PHV(12.8 ± 0.6) Circum-PHV(14.2 ± 0.8) Post-PHV(15.6 ± 1.5)	U14(-0.9 ± 0.7) U16(0.6 ± 1.0) U18 (2.0 ± 0.6) Pre(-1.5 ± 0.3) Circum(-0.2 ± 0.6) Post(1.8 ± 0.2)	U14(155.9 ± 7.3) U16(165.4 ± 9.0) U18 (170.8 ± 7.5) Pre(150.7 ± 5.4) Circum(160.6 ± 6.1) Post(172.2 ± 6.5)	U14(43.9 ± 8.1) U16(52.9 ± 10.1) U18 (61.4 ± 9.8) Pre(38.5 ± 3.5) Circum(48.1 ± 7.5) Post(61.8 ± 8.4)	N/A	**(Σ7 Skin-folds, mm)** U14(51.8 ± 22.3) U16(52.9 ± 10.1) U18(61.4 ± 9.8) Pre(48.6 ± 12.6) Circum(49.0 ± 20.8) Post(47.2 ± 10.0)
Candhas, 2010	South American (Brazilian)	Elite	U10 - U13	N/A	U10(140.6 ± 8.2) U11(143.9 ± 8.0) U12(150.5 ±8.2) U13(158.2 ± 10.4	U10(34.7 ± 7.0) U11(35.9 ± 6.2) U12(40.2 ± 7.8) U13(46.5 ± 10.4)	U10(17.4 ± 2.2) U11(17.2 ± 1.7) U12(17.7 ± 2.1) U13(18.3 ± 1.9)	U10(14.8 ± 5.1) U11(13.1 ± 5.6) U12(14.5 ± 5.8) U13(13.9 ± 5.2)
Carling, 2012	European (French)	Elite	All(13.5 ± 0.4) Late(13.5 ± 0.3) On time(13.5 ± 0.4) Early(13.5 ± 0.6)	Skeletal Age:13.7 ±1.4 SACA ratio: 0.25 ± 1.29 Late(-1.5 ± 0.3) On time(0.1 ± 0.6) Early(2.1 ± 0.8)	162.4 ± 9.2 Late(152.9 ± 5.1) On time(163.5 ± 8.2) Early(171 ± 6.2)	52.0 ± 9.5 Late(40.6 ± 3.4) On time(52.0 ± 8.2) Early(60.6 ± 6.6)	N/A	12.4 ± 2.3 Late(11.5 ± 2.5) On time(12.4 ± 2.2) Early(12.9 ± 2.5)
Castagna, 2003	European (Italian)	N/A	11.8 ± 0.6	N/A	150 ± 5	40.5 ± 5.2	N/A	N/A
Coelho e Silva, 2010	European (Portuguese)	Elite and Non-Elite	LL(13.6 ± 0.3) EL13.7 ± 0.3)	Skeletal Age: LL(14.1 ± 1.0) EL(15.0 ± 0.9) SACA: LL(0.5 ± 1.1) EL(1.3 ± 0.8)	LL(158.6 ± 8.2) EL(167.1 ± 6.9)	LL(48.6 ± 8.9) EL(56.7 ± 5.7)	N/A	**(Σ4 Skinfolds,mm)** LC(37.0 ± 15.3) EL(32.8 ± 8.6)
Comfort, 2013	European (English)	Elite	17.2 ± 0.6	N/A	179.27 ± 6.58	72.62 ± 7.42	N/A	N/A
Cunha, 2016	South American (Brazilian)	Elite	U11-12, U13-14, U15-16, >U17	Pre(12.7 ± 0.8), Pub(14.2 ± 1.4), PosP(16.8 ± 1.4)	Pre(161.2 ± 8.7) Pub(171.1 ± 7.6) PosP(179.0 ± 6.6) 11-12(160.6 ± 8.5) 13-14(169.9 ± 7.5) 15-16(177.0 ± 6.9) >17(179.7 ± 6.0)	Pre(51.3 ± 8.0) Pub(64.9 ± 9.7) PosP(74.2 ± 6.4) 11-12(52.8 ± 10.1) 13-14(63.4 ± 9.7) 15-16(71.3 ± 6.8) >17(75.0 ± 6.9)	N/A	N/A
Deprez, 2015	European (Belgian)	Elite	2FUP: T1(13.2 ± 0.3) T2(14.2 ± 0.3) T3(15.2 ± 0.3) 4FUP: T1(12.2 ± 0.3) T2(14.2 ± 0.3) T3(16.2 ± 0.3)	2FUP: T1(-0.85 ± 0.51) T2(0.14 ± 0.72) T3(1.17 ± 0.70) 4FUP: T1(-1.72 ± 0.34) T2(0.28 ± 0.61) T3(2.14 ± 0.47)	2FUP: T1(157.8 ± 6.5) T2(164.8 ± 7.5) T3(171.1 ± 6.5) 4FUP: T1(150.7 ± 3.6) T2(165.2 ± 5.2) T3(174.6 ± 3.9)	2FUP: T1(46.0 ± 6.8) T2(52.7 ± 8.7) T3(59.3 ± 8.8) 4FUP: T1(39.5 ± 4.4) T2(52.3 ± 7.2) T3(62.9 ± 5.1)	N/A	N/A
Figueiredo, 2009	European (Portuguese)	Elite and Non-Elite	U11-12:Drop out(11.7 ± 0.6) Club(11.8 ± 0.5) Elite(12.1 ± 0.6) U13-14:Drop out(13.8 ± 0.2) Club(14.1 ± 0.6) Elite(14.5 ± 0.6)	SA U11-12: D(11.9 ± 1.6) C(11.9 ± 1.3) E(12.5 ± 1.5) SA U13-14: D(14.0 ± 0.9) C(14.5 ± 1.2) E(15.3 ± 0.9) SA-CA U11-12: D(0.2 ± 1.8) C(0.1 ± 1.3) E(0.5 ± 1.4) SA-CA U13-14: D(0.2 ± 0.9) C(0.4 ± 1.1) E(0.8 ± 1.1)	U11-12: D(143.6 ± 6.1) C(143.7 ± 5.9) E(150.8 ± 8.3) U13-14: D(157.5 ± 8.7) C(162.7 ± 9.8) E(169.2 ± 5.1)	U11-12: D(39.5±6.4) C(36.5±5.0) E(42.4±8.3) U13-14: D(49.4±8.4) C(53.0±10.8) E(59.2±7.7)	N/A	**(Σ4 Skinfolds,mm)** U11-12: D(35.9 ± 21.0) C(31.2 ± 10.7) E(31.3 ± 15.8) U13-14: D(39.3 ± 17.7) C(36.2 ± 17.2) E(34.3 ± 12.6)
Figueiredo, 2011	European (Portuguese)	Elite	U11-12(11.8 ± 0.5) U13-14(14.2 ± 0.6)	U11-12(12.0 ± 1.4) U13-14(14.6 ± 1.1) SA-CA U11-12 (1.02 ± 0.12) U13-14(1.03 ± 0.07)	U11-12(144.7 ± 7.0) U13-14(163.6 ± 9.5)	U11-12(38.1 ± 6.2) U13-14(54 ± 10.0)	N/A	N/A
Forsman, 2015	European (Finnish)	Elite	12.7 ± 0.6	N/A	156.3 ± 8.5	44.9 ± 8.1	N/A	N/A
Forsman, 2016	European (Finnish)	Elite and Non-Elite	E(15.48±0.23) NE(15.39±0.27)	N/A	E(176.71 ± 7.85) SE(173.72 ± 7.40)	E(66.14 ± 9.04), SE(61.92 ± 8.91)	N/A	N/A
Gil, 2014	European (Spanish)	Elite and Non-Elite	Outfield(9.84 ± 0.27) Goalkeeper(9.91 ± 0.13) Soccer Club (9.63±0.29)	OF(13.62 ± 0.25) GK(13.51 ± 0.22) SC(13.03 ± 0.36) OF(-3.79 ± 0.32) GK(-3.59 ± 0.25) SC(-3.22 ± 0.42)	OF(139.16 ± 5.44) GK(143.44±5.35) SC(140.27±7.03)	OF(32.96 ± 4.28) GK(38.13 ± 3.72) SC(35.45 ± 7.03)	OF(16.93 ± 1.43) GK(18.50 ± 1.08) SC(17.89 ± 2.01)	**Σ6 Skinfolds, mm** OF(48.86 ± 15.50) GK:63.28±14.72 SC 66.16±29.75 **% Fat -** OF(9.84±1.25) GK (11.30±1.35)
Gissis, 2006	European (Greek)	Elite, Subelite and Non-Elite	Elite(16.3 ± 1.3), SubElite(16.4 ± 1.3), Recreational(16.2 ± 1.29)	N/A	E(169.1 ± 5.7) SE(168.6 ± 4.8) REC(168.8 ± 4.6)	E(68.17 ± 6.9) SE(67.74 ± 7.5) REC(69.87 ± 7.6)	N/A	N/A
Hill-Haas, 2009	Australian	Elite	16.3 ± 0.6	N/A	174 ± 0.08	65.0 ± 9.8	N/A	N/A
Hirose, 2015	Asian (Japanese)	Elite	U13(13.2±0.2), U15(15.2±0.2)	APHV(13.2±0.2) APHV - CA U13-U15 (-0.1±0.6) U15-U17 (1.5±0.3)	U13-U15: U13 (165.0 ± 6.9) U15(174.0 ± 5.3) U15-U17: U15 (171.7 ± 3.6) U17(175.3 ± 4.2)	U13-U15: U13(51.5 ± 8.6) U15(62.3 ± 7.6) U15-U17: U15(59.1 ± 4.0) U17(65.8 ± 5.4)	N/A	N/A
Honer, 2014	European (German)	Elite	U12, U13, U14, U15	N/A	Autumn CC - U12(148.6) U13(154.3) U14(161.6) U15(169.1) YA - U12(148.9) U13(155.4 U14:163.4 U15:170.7 Spring CC - U12:150.8 U13:157.1 U14:164.7 U15:172 YA - U12:151.2 U13:158.9 U14:167.1 U15:173.0	Autumn CC - U12: 38.0 U13: 42.1 U14: 48.1 U15: 55.7 YA - U12: 38.2 U13: 42.6 U14: 50.1 U15: 58.3 Spring CC - U12: 39.7 U13: 44.6 U14: 51.5 U15: 59.2 YA - U12: 40.0 U13: 45.4 U14: 54.1 U15: 60.8	N/A	N/A
Huijgen, 2014	European (Dutch)	Elite	Selected(17.04 ± 0.69) Deselected(17.21 ± 0.73)	N/A	S(177 ± 0.07), DS(178 ± 0.07)	S(70.44 ± 7.79) DS(69.88 ± 6.77)	N/A	S(8.29 ± 2.68) DS(8.05 ± 2.93)

Table 2 continued.

Author and Year	Population	Playing Level	Chronological Age	Maturity Onset/Age Peak Height Velocity	Height (cm)	Weight (Kgs)	BMI	Fat Percentage
Le Gall, 2008	European (French)	Elite and Non-Elite	U14: International(13.4 ± 0.4), Professional(13.6 ± 0.4), Amateur(13.5 ± 0.5) U15: I(14.4 ± 0.4), P(14.5 ± 0.4), A(14.4 ± 0.4) U16: I(15.4 ± 0.4), P(15.4 ± 0.4), A(15.5 ± 0.5)	SA-CA U14: I(-0.2 ± 1.1), P(0.1 ± 1.2), A(0.4±1.4) U15: I(0.1 ± 1.5), P(0.4 ± 1.4), A(0.9 ± 1.4) U16: I(0.0 ± 1.5), P(0.9 ± 1.5), A(1.1 ± 1.5)	U14: I(165.2 ± 10.5), P(165 ± 8.8), A(162.1 ± 9.0) U15: I(171.5 ± 9.4), P(170.8 ± 8.0), A(169.1 ± 8.2) U16: I(176.1 ± 7.5), P(175.3 ± 8.2), A(169.1 ± 8.2)	U14: I(52.5 ± 9.9), P(53.8 ± 9.5), A(50.8 ± 9.2) U15: I(59.3±10.3), P(60.3 ± 9.2), A(58.8 ± 9.2) U16: I(65.3 ± 8.8), P(66.0 ± 8.2), A(58.8 ± 9.2)	N/A	U14: I(11.9 ± 1.42), P(12.5 ± 2.6), A(12.4 ± 2.3) U15: I(11.6 ± 1.80), P(13.0 ± 5.0), A(12.6 ± 2.5) U16: I(11.3 ± 1.50), P(12.6 ± 2.3), A(12.6 ± 2.5)
Lovell, 2015	European (English)	Elite	U10: Q1(10.1±0.5) Q2(9.8±0.6) Q3(9.8±0.6) Q4(9.6±0.6) U12: Q1(11.9±0.5) Q2(11.9±0.5) Q3(11.5±0.5) Q4(11.2±0.5) U14: Q1(13.9±0.5) Q2(13.8±0.6) Q3(13.4±0.5) Q4(13.2±0.5) U16: Q1(15.7±0.4) Q2(15.5±0.4) Q3(15.3±0.5) Q4(14.9±0.5) U18: Q1(17.7±0.5) Q2(17.4±0.6) Q3(17.1±0.6) Q4(17.1±0.6)	U10: Q1(13.4±0.4) Q2(13.2±0.4) Q3(13.1±0.4) Q4(12.9±0.5) U12: Q1(14.0±0.5) Q2(13.9±0.4) Q3(13.8±0.5) Q4(13.8±0.3) U14: Q1(14.2±0.6) Q2(14.1±0.6) Q3(14.2±0.6) Q4(14.1±0.7) U16: Q1(14.2±0.6) Q2(14.2±0.6) Q3(14.1±0.4) Q4(14.0±0.6) U18: Q1(14.8±0.6) Q2(14.7±0.6) Q3(14.5±0.5) Q4(14.5±0.5)	U10: Q1(138.5±5.9) Q2(139.2±4.0) Q3(139.9±5.7) Q4(142.0±6.2) U12: Q1(149.3±7.7) Q2(150.4±8.6) Q3(147.5±6.9) Q4(145.2±6.3) U14: Q1(164.2±9.2) Q2(163.8±9.2) Q3(160.5±9.3) Q4(158.8±8.4) U16: Q1(175.6±6.3) Q2(174.1±7.0) Q3(175.3±6.1) Q4(173.4±8.1) U18: Q1(178.4±6.3) Q2(179.4±5.7) Q3(179.8±5.8) Q4(178.6±5.6)	U10: Q1(33.4±4.3) Q2(33.4±3.6) Q3(34.3±4.6) Q4(34.5±4.0) U12: Q1(40.4±6.7) Q2(40.8±6.7) Q3(38.2±5.3) Q4(36.9±4.8) U14: Q1(52.3±9.3) Q2(52.5±8.7) Q3(49.7±9.0) Q4(48.2±8.3) U16: Q1(65.0±7.2) Q2(62.6±7.3) Q3(64.5±7.1) Q4(65.1±7.2) U18: Q1(73.0±6.3) Q2(73.2±7.2) Q3(72.9±5.8) Q4(73.1±6.8)	N/A	N/A
Malina, 2000	European (Portuguese)	Elite	U11-U12(12.34 ± 0.52), U13-U14(13.65 ± 0.70) U15-U16(15.70 ± 0.35), U15-U16(16.06 ± 0.22) (Non-Skeletally mature and Skeletally Mature U15-U16)	U11-U12(12.34 ± 0.52), U13-U14(13.65 ± 0.70) U15-U16(15.70 ± 0.35), U15-U16(16.06 ± 0.22)	U11-U12(151 ± 0.08), U13-U14(163 ± 0.08) U15-U16(174 ± 0.06), U15-U16(172 ± 0.07)	U11-U12(43.1 ± 7.0), U13-U14(52.5 ± 8.7) U15-U16(64.1 ± 5.3), U15-U16(70.0 ± 8.7)	N/A	N/A
Mendez-Villanuev, 2010	Middle East (Qatarian)	Elite	Pre-PHV(12.3 ± 0.7), Circum-PHV(14.3 ± 0.9), Post-PHV(16.9 ± 0.7)	Pre(-2.1 ± 0.4), Circum(-0.2 ± 0.7), Post(2.3 ± 0.4)	Pre(145.9 ± 4.4), Circum(160.7 ± 6.3), Post (173.3 ± 4.4)	Pre(35.4 ± 3.7), Circum(47.7 ± 5.2), Post (62.1 ± 6.9)	Pre(16.6 ± 1.5), Circum(18.4 ± 1.2), Post(20.6 ± 1.9)	Σ7 Skin-folds, mm: Pre(48.6 ± 11.5), Circum(49.1 ± 18.4), Post(48.7 ± 10.6)
Mendez-Villanuev, 2011	Middle East (Qatarian)	Elite	U14(12.7 ± 0.7), U16(14.9 ± 0.6), U18(17.0 ± 0.6)	U14(-1.7 ± 0.7), U16(0.4 ± 0.9), U18(2.2 ± 0.6)	U14(150.0 ± 7.0), U16(165.0 ± 8.0), U18(173.0 ± 5.0)	U14(38.6 ± 5.5), U16(51.0 ± 7.6), U18(61.9 ± 6.6)	U14(17.2 ± 1.5), U16(18.6 ± 1.6), U18(20.8 ± 1.7)	U14(9.7 ± 3.5), U16(9.2 ± 1.6), U18(10.0 ± 2.4)
Mendez-Villanuev, 2012	Middle East (Qatarian)	Elite	U13 (12.5±0.3) U14 (13.4±0.3) U15 (14.3±0.3) U16 (15.6±0.3) U17 (16.4±0.2) U18 (17.3±0.3)	N/A	U13(149.2 ± 6.8), U14(158.3 ± 7.2), U15(161.3 ± 7.4), U16(164.2 ± 8.1), U17(171.5 ± 6.2), U18(171.1 ± 9.5)	U13(38.2 ± 5.4), U14(43.8 ± 5.1), U15(48.9 ± 10.1), U16(51.1 ± 6.9), U17(57.5 ± 4.8), U18(56.3 ± 7.5)	N/A	N/A
Portas, 2015	European (English)	Elite	U9, U10, U11, U12, U13, U14, U15, U16, U18	U9 PrePHV(90), U10 PrePHV(103), U11 PrePHV(116), U12 PrePHV(111), U13 PrePHV(106) PostPHV(3), U14 PrePHV(112) PostPHV(23), U15 PrePHV(24) PostPHV(104) , U16 PrePHV(3) PostPHV(118), U18 PostPHV(250)	U9(132.7 ± 5.6), U10(136.9 ± 5.8), U11(142.5 ± 6.1), U12(148.6 ± 6.4), U13(154.7 ± 7.1), U14(162.4 ± 8.4), U15(171.6 ± 7.0), U16(175.9 ± 6.4), U18(179.0 ± 6.3)	U9(29.3 ± 4.2), U10(32.4 ± 4.4), U11(36.1 ± 5.4), U12(39.3 ± 5.2), U13(44.3 ± 7.3), U14(50.2 ± 8.4), U15 (61. ± 12.7) U16(66.3 ± 7.6) U18(72.5 ± 6.9)	N/A	N/A
Reilly, 2000	European (English)	Elite and Non-Elite	Elite (16.4) Non-Elite (16.4)	N/A	E(171.0 ± 5.0), NE (170.0 ± 6.0)	E(63.1 ± 1.1), NE (66.4 ± 2.5)	N/A	E(11.3 ± 2.1) NE (13.9 ± 3.8)
Saward, 2015	European (English)	Elite	U9(9.2 ± 0.3), U10(10.2 ± 0.3), U11(11.1 ± 0.3), U12(12.2 ± 0.3), U13(13.1 ± 0.3), U14(14.1 ± 0.3), U15(15.0 ± 0.4), U16(16.0 ± 0.4), U17(17.0 ± 0.3), U18(18.0 ± 0.3)	N/A	U9(137.6 ± 5.4), U10(142.8 ± 5.6), U11(146.9 ± 3.9), U12(154.0 ± 7.2), U13(161.9 ± 9.4), U14(170.7 ± 6.8), U15(175.7 ± 6.2), U16(178.0 ± 6.4), U17(178.2 ± 6.8), U18(179.8 ± 5.3)	U9(31.4 ± 5.0), U10(35.5 ± 6.7), U11(38.1 ± 4.8), U12(42.8 ± 6.6), U13(49.8 ± 9.3), U14(59.1 ± 8.5), U15(65.8 ± 7.1), U16(70.1 ± 6.5), U17(73.6 ± 5.8), U18(73.3 ± 5.7)	N/A	N/A
Stroyer, 2004	European (Danish)	Elite and Non-Elite	Non-elite beginning of Puberty(12.1±0.7), Elite beginning of Puberty(12.6±0.6), Elite end of Puberty (14.0±0.2)	N/A	NbP(153.1 ± 5.1), EbP(154.1 ± 8.2), EeP(172.2 ± 6.1)	NbP(40.6 ± 6.6), EbP(42.5 ± 7.2), EeP(57.5 ± 7.2)	NbP(17.2 ± 2.2), EbP(17.8 ± 2.0), EeP(19.3 ± 1.9)	N/A
Towlson, 2017	European (English)	Elite	U13-U14: 13.8(95% CI: 13.6 - 13.9) U15-U16: 15.6(15.4 - 15.7) U17-U18: 17.8 (17.6 - 17.9)	U13-U14: 14.1 (14.0 - 14.3) U15-U16: 14.2 (14.1 - 14.4) U17-U18: 14.9 (1.48 - 15.0)	U13-U14: 164.6 (163.4 - 165.8) U15-U16: 174.8 (173.1 - 176.4) U17-U18: 187.7 (177.2 - 180.1)	U13-U14: 52.3 (50.7 - 53.8) U15-U16: 64.5 (62.5 - 66.3) U17-U18: 72.3 (70.6 - 74.0)	N/A	N/A
Vadendriessche, 2012	European (Belgian)	Elite	U16(15.3 ± 0.3), U16F(15.2 ± 0.3) U17(16.2 ± 0.3), U17F(16.1 ± 0.3)	U16(13.6 ± 0.5), U16F(14.3 ± 0.5) U17(13.8 ± 0.5), U17F(14.9 ± 0.4)	U16(175.3 ± 8.5), U16F(167.9 ± 6.3) U17(176.8 ± 5.9), U17F(167.8 ± 4.8)	U16(64.0 ± 6.8), U16F(54.4 ± 6.4) U17(67.9 ± 6.7), U17F(53.2 ± 5.1)	U16(20.8 ± 1.5), U16F(19.0 ± 1.8) U17(21.7 ± 1.3), U17F(19.1 ± 1.2)	U16(10.4 ± 2.4), U16F(8.7 ± 1.6) U17(12.3 ± 3.0), U17F(8.0 ± 2.6)
Vaeyens, 2006	European (Belgian)	Elite and Non-Elite	12.2 ± 0.7, range 10.4–13.7	N/A	U13: E(151.8 ± 6.6) SE(151.5 ± 5.8) NE(153.5 ± 7.6) U14: E(157.7 ± 8.4) SE(161.3 ± 7.7) NE(160.5 ± 8.4) U15: E(167.5 ± 8.8) SE(167.9 ± 7.5) NE(168.4 ± 9.2) U16: E(171.7 ± 7.4) SE(174.0 ± 8.3) NE(175.1 ± 7.9)	U13: E(40.3 ± 6.1) SE(40.8 ± 4.8) NE(42.3 ± 8.7) U14: E(44.3 ± 6.5) SE(48.0 ± 7.8) NE(46.7 ± 8.8) U15: E(53.4 ± 9.6) SE(52.9 ± 8.5) NE(54.5 ± 10.6) U16: E(57.9 ± 8.2) SE(60.6 ± 9.8) NE(60.5 ± 9.4)	N/A	Σ11 Skin-folds, mm: U13: E(40.3 ± 6.1) SE(40.8 ± 4.8) NE(42.3 ± 8.7) U14: E(44.3 ± 6.5) SE(48.0 ± 7.8) NE(46.7 ± 8.8) U15: E(53.4 ± 9.6) SE(52.9 ± 8.5) NE(54.5 ± 10.6) U16: E(57.9 ± 8.2) SE(60.6 ± 9.8) NE(60.5 ± 9.4)
Valente dos Santos, 2012	European (Portuguese)	Elite	11(11.6 ± 0.3), 12(12.6 ± 0.3), 13(13.7 ± 0.3), 14(14.7 ± 0.3), 15(15.7 ± 0.3), 16(16.7 ± 0.3), 17(17.6 ± 0.3)	Skeletal Age 11Y(11.8 ± 1.0), 12Y(12.7 ± 1.2), 13Y(14 ± 1.1), 14Y(15 ± 1.1), 15Y(16.3 ± 0.7), 16Y(17.1 ± 0.3), 17Y(17.7 ± 0.2)	11Y(143.1 ± 6.0), 12Y(149.3 ± 7.1), 13Y(158.0 ± 8.1), 14Y(164.9 ± 7.6), 15Y(169.9 ± 6.4), 16Y(172.5 ± 5.2), 17Y(173.7 ± 4.2)	11Y(36.4 ± 5.3), 12Y(40.5 ± 6.4), 13Y(47.4 ± 8.6), 14Y(53.7 ± 8.5), 15Y(59.9 ± 8.6), 16Y(64.4 ± 9.6), 17Y(68.0 ± 9.4)	N/A	N/A
Vänttinen, 2010	European (Finnish)	Elite and Non-Elite	10 years, 12 years, 14 years	N/A	10Y(144.0 ± 6), 12Y(157.0 ± 11.0), 14Y(168 ± 8)	10Y(33.2 ± 4.0), 12Y(42.3 ± 8.4), 14Y(54.0 ± 7.8)	N/A	10Y(9.4 ± 3.5), 12Y(9.7 ± 3.8), 14Y(7.8 ± 3.5)
Vänttinen, 2011	European (Finnish)	Elite and Non-Elite	Group 1:10.8 ± 0.3 Group 2:12.7 ± 0.2 Group 3:14.7 ± 0.3	N/A	Group 1: 11Y(142.0 ± 7.0), 12Y(147 ± 7.0), 13Y(153 ± 9.0), 13Y(152.0 ± 10.0) Group 2: 14Y(160 ± 10.0), 15Y(168.0 ± 10.0), 15Y(165.0 ± 8.0) Group 3: 16Y(171.0 ± 6.0), 17Y(175.0 ± 4.0)	Group 1: 11Y(33.0 ± 4.0), 12Y(36.5 ± 5.1), 13Y(40.2 ± 5.9), 13Y(42.6 ± 7.5) Group 2: 14Y(48.7 ± 9.1), 15Y(53.9 ± 9.5), 15Y(57.2 ± 11.2) Group 3: 16Y(62.8 ± 10.4), 17Y(65.9 ± 10.2)	N/A	Group 1: 11Y(9.2 ± 3.4), 12Y(11.1 ± 3.5), 13Y(10.1 ± 4.1), 13Y(10.7 ± 4.2) Group 2: 14Y(10.7 ± 4.3), 15Y(8.8 ± 2.9), 15Y(9.9 ± 6.6) Group 3: 16Y(9.0 ± 5.0), 17Y(8.5 ± 6.0)
Wong, 2009	Asian (Chinese)	Elite	16.2 ± 0.6	N/A	173 ± 5.2	64.2 ± 8.1	N/A	N/A
Wong, 2009	Asian (Hong Kong)	Elite	U14 GK (13.4±0.7) DF(13.3±0.8) MF(13.4±0.6) FW(13.0±0.8)	N/A	GK (169±0.06) DF(167±0.07) MF(165±0.08) FW(156±0.11)	GK (54.6±7.3) DF(56.2±6.2) MF(52.2±9.6) FW(43.9±9.5)	GK (19.2±1.9) DF(20.3±2.2) MF(19.0±2.5) FW(17.7±1.5)	N/A

Table 3. Physical results from football specific studies

Author and Year	Population	Playing Level	Ages (Year)	Maturity Onset	Power (Countermovement Vertical Jump, cm)	Agility	Acceleration (seconds)	Speed (seconds)	Aerobic Capacity
Bidaurrazaga, 2014	European (Spanish)	Elite	Year 1: Preseason(10.9 ± 0.7) End of Season(11.5 ± 0.7) Year 2: PS(12.0 ± 0.6) ES(12.7 ± 0.9) Year 3: PS(12.8 ± 0.6) ES(13.5 ± 0.6) Year 4: PS(13.7 ± 0.6) ES(14.3 ± 0.5)	N/A	Year 1: Preseason(35.9 ± 4.7) End of Season(32.4 ± 4.1) Year 2: PS(34.0 ± 4.6) ES(35.5 ± 4.7) Year 3: PS(35.4 ± 4.4) ES(37.7 ± 4.5) Year 4: PS(38.9 ± 4.1) ES(41.7 ± 4.3)	N/A	N/A	N/A	N/A
Buchheit, 2010	Middle East (Qatarian)	Elite	U13(7) U14(17) U15(10) U16(12) U17(17) U18(14)	U13 (-1.7 ± 0.4) U14 (-0.7 ± 0.5) U15 (-0.1 ± 0.7) U16 (0.6 ± 0.8) U17 (1.6 ± 0.6) U18 (2.2 ± 0.4)	U13(27.5 ± 2.5), U14(32.0 ± 3.1), U15(39.2 ± 4.1), U16(37.9 ± 3.7), U17(42.6 ± 4.0), U18(44.5 ± 5.2)	N/A	U13(1.96 ± 0.07), U14(1.89 ± 0.06), U15(1.79 ± 0.08) U16(1.77 ± 0.05), U17(1.74 ± 0.04) U18 (1.71 ± 0.06)	N/A	N/A
Buchheit, 2013	Middle East (Qatarian)	Elite	U14(13.2 ± 0.6) U16(15 ± 0.6) U18(16.9 ± 0.6) Pre-PHV(12.8 ± 0.6) Circum-PHV(14.2 ± 0.8) Post-PHV(15.6 ± 1.5)	U14(-0.9 ± 0.7) U16(0.6 ± 1.0) U18 (2.0 ± 0.6) Pre(-1.5 ± 0.3) Circum(-0.2 ± 0.6) Post(1.8 ± 0.2)	U14(33.0 ± 4.5), U16(39.6 ± 5.1), U18 (47.2 ± 6.1), Pre(29.6 ± 3.7), Circum(37.4 ± 4.7), Post(42.8 ± 7.1)	N/A	U14(1.89 ± 0.09), U16(1.81 ± 0.09), U18(1.71 ± 0.05), Pre(1.92 ± 0.05), Circum(1.85 ± 0.10), Post(1.76 ± 0.08)	N/A	N/A
Carling, 2012	European (French)	Elite	All(13.5 ± 0.4) Late(13.5 ± 0.3) On time(13.5 ± 0.4) Early(13.5 ± 0.6)	Skeletal Age:13.7 ±1.4 *SACA ratio: 0.25 ± 1.29 Late(-1.5 ± 0.3), On time(0.1 ± 0.6), Early(2.1 ± 0.8)	All(42.9 ± 5.8) Late(39.4 ± 5.2), On time(42.9 ± 5.8), Early(45.5 ± 4.8)	N/A	All(1.96 ± 0.09) Late(2.01 ± 0.08), On time(1.96 ± 0.09), Early(1.90 ± 0.60)	20m: All(3.33 ± 0.14) Late(3.44 ± 0.11), On time(3.34 ± 0.13), Early(3.23 ± 0.12) 40m: All(5.91 ± 0.28) Late(6.16 ± 0.21), On time(5.92 ± 0.27), Early(5.67 ± 0.17)	N/A
Comfort, 2013	European (English)	Elite	17.2 ± 0.6	N/A	46.35 ± 9.06	N/A	5m: 1.0 ± 0.06	20m: 3.00 ± 0.13	N/A
Deprez, 2015	European (Belgian)	Elite	**2FUP: T*1(13.2 ± 0.3) T2(14.2 ± 0.3) T3(15.2 ± 0.3) 4FUP: T1(12.2 ± 0.3) T2(14.2 ± 0.3) T3(16.2 ± 0.3)	2FUP: T1(-0.85 ± 0.51) T2(0.14 ± 0.72) T3(1.17 ± 0.70) 4FUP: T1(-1.72 ± 0.34) T2(0.28 ± 0.61) T3(2.14 ± 0.47)	N/A	N/A	N/A	N/A	2FUP: T1(1319 ± 366), T2(1705 ± 371), T3(1823 ± 427) 4FUP: T1(1090 ± 366), T2(1749 ± 406), T3(2175 ± 388)
Figueiredo, 2009	European (Portuguese)	Elite and Non Elite	U11-12:Drop out(11.7 ± 0.6) Club(11.8 ± 0.5) Elite(12.1 ± 0.6) U13-14:Drop out(13.8 ± 0.2) Club(14.1 ± 0.6) Elite(14.5 ± 0.6)	SA U11-12: D(11.9 ± 1.6) C(11.9 ± 1.3) E(12.5 ± 1.5) SA U13-14: D(14.0 ± 0.9) C(14.5 ± 1.2) E(15.3 ± 0.9) SA-CA U11-12: D(0.2 ± 1.8) C(0.1 ± 1.3) E(0.5 ± 1.4) SA-CA U13-14: D(0.2 ± 0.9) C(0.4 ± 1.1) E(0.8 ± 1.1)	U11-12: D(25.5 ± 5.3) C(25.8 ± 4.1) E(29.0 ± 4.4) U13-14: D(29.7 ± 4.3) C(31.9 ± 5.5) E(33.7 ± 3.3)	N/A	N/A	N/A	U11-12: D(1000 ± 562), C(1376 ± 697), E(1997 ± 755) U13-14: D(2344 ± 939), C(2385 ± 852), E(2998 ± 878)
Forsman, 2016	European (Finnish)	Elite and Non Elite	E(15.48 ± 0.23), NE(15.39 ± 0.27)	N/A	E(36.52 ± 4.42), NE(35.20 ± 4.50)	N/A	N/A	30m: E(4.41 ± 0.15), NE(4.55 ± 0.23)	E(2501 ± 325), NE(2301 ± 359)
Gil, 2014	European (Spanish)	Elite and Non Elite	Outfield(9.84 ± 0.27) Goalkeeper(9.91 ± 0.13) Soccer Club (9.63±0.29)	OF(13.62 ± 0.25) GK(13.51 ± 0.22) SC(13.03 ± 0.36) OF(-3.79 ± 0.32) GK(-3.59 ± 0.25) SC(-3.22 ± 0.42)	OF(29.07 ± 3.27) GK(27.43 ± 1.87) SC(26.87 ± 3.07)	N/A	N/A	30m: OF(4.96 ± 0.21) GK(5.05 ± 0.20) SC(5.53 ± 0.30)	OF(617.95 ± 233.24) GK(408.88 ± 79.44) SC(463.52 ± 223.27)
Gissis, 2006	European (Greek)	Elite, Subelite and Recreational	Elite(16.3 ± 1.3) SubElite(16.4 ± 1.3) Recreational(16.2 ± 1.29)	N/A	N/A	N/A	E(1.95 ± 0.34), SE(2.14 ± 0.41), REC(2.21 ± 0.45)	N/A	N/A
Le Gall, 2008	European (French)	Elite and Non-Elite	U14: International(13.4 ± 0.4), Professional(13.6 ± 0.4), Amateur(13.5 ± 0.5) U15: I(14.4 ± 0.4), P(14.5 ± 0.4), A(14.4 ± 0.4) U16: I(15.4 ± 0.4), P(15.4 ± 0.4), A(15.5 ± 0.5)	SA-CA U14: I(-0.2 ± 1.1), P(0.1 ± 1.2), A(0.4 ± 1.4) U15: I(0.1 ± 1.5), P(0.4 ± 1.4), A(0.9 ± 1.4) U16: I(0.0 ± 1.5), P(0.9 ± 1.5), A(1.1 ± 1.5)	U14: I(43.7 ± 7.2), P(42.6 ± 5.8), A(42.8 ± 5.5) U15: I(47.9 ± 6.1), P(46.3 ± 5.5), A(45.1 ± 5.3) U16: I(50.6 ± 6.4), P(49.4 ± 5.7), A(47.8 ± 4.9)	N/A	U14: I(1.96 ± 0.10), P(1.95 ± 0.09), A(1.96 ± 0.08) U15: I(1.87 ± 0.08), P(1.89 ± 0.08), A(1.89 ± 0.07) U16: I(1.82 ± 0.10), P(1.85 ± 0.08), A(1.85 ± 0.07)	20m: U14: I(3.34 ± 0.14), P(3.32 ± 0.14), A(3.33 ± 0.14) U15: I(3.17 ± 0.13), P(3.20 ± 0.14), A(3.22 ± 0.11) U16: I(3.06 ± 0.16), P(3.12 ± 0.12), A(3.11 ± 0.24) 40m: U14: I(5.88 ± 0.29), P(5.91 ± 0.29), A(5.91 ± 0.28) U15: I(5.52 ± 0.40), P(5.63 ± 0.26), A(5.69 ± 0.23) U16: I(5.40 ± 0.29), P(5.47 ± 0.22), A(5.52 ± 0.18)	N/A
Lovell, 2015	European (English)	Elite	U10: Q1(10.1±0.5) Q2(9.8±0.6) Q3(9.8±0.6) Q4(9.6±0.6) U12: Q1(11.9±0.5) Q2(11.9±0.5) Q3(11.5±0.5) Q4(11.2±0.5) U14: Q1(13.9±0.5) Q2(13.8±0.6) Q3(13.4±0.5) Q4(13.2±0.5) U16: Q1(15.7±0.4) Q2(15.5±0.4) Q3(15.3±0.5) Q4(14.9±0.5) U18: Q1(17.7±0.5) Q2(17.4±0.6) Q3(17.1±0.6) Q4(17.1±0.6)	U10: Q1(13.4±0.4) Q2(13.2±0.4) Q3(13.1±0.4) Q4(12.9±0.5) U12: Q1(14.0±0.5) Q2(13.9±0.4) Q3(13.8±0.5) Q4(13.8±0.3) U14: Q1(14.2±0.6) Q2(14.1±0.6) Q3(14.2±0.6) Q4(14.1±0.7) U16: Q1(14.2±0.6) Q2(14.2±0.6) Q3(14.1±0.4) Q4(14.0±0.6) U18: Q1(14.8±0.6) Q2(14.7±0.6) Q3(14.5±0.5) Q4(14.5±0.5)	N/A	N/A	U10: Q1(1.96±0.12) Q2(1.95±0.09) Q3(1.95±0.06) Q4(1.94±0.07) U12: Q1(1.85±0.09) Q2(1.85±0.09) Q3(1.87±0.06) Q4(1.89±0.08) U14: Q1(1.71±0.10) Q2(1.71±0.09) Q3(1.74±0.08) Q4(1.72±0.07) U16: Q1(1.61±0.08) Q2(1.61±0.07) Q3(1.63±0.11) Q4(1.63±0.09) U18: Q1(1.59±0.06) Q2(1.60±0.05) Q3(1.61±0.04) Q4(1.58±0.06)	**20m** U10: Q1(3.61±0.22) Q2(3.57±0.18) Q3(3.57±0.10) Q4(3.54±0.14) U12: Q1(3.40±0.18) Q2(3.38±0.17) Q3(3.44±0.10) Q4(3.48±0.15) U14: Q1(3.12±0.20) Q2(3.11±0.16) Q3(3.17±0.15) Q4(3.16±0.15) U16: Q1(2.92±0.12) Q2(2.91±0.13) Q3(2.95±0.20) Q4(2.94±0.17) U18: Q1(2.87±0.11) Q2(2.87±0.08) Q3(2.90±0.08) Q4(2.85±0.10)	**MSFT** U10: Q1(1180±332) Q2(1265±259) Q3(1237±315) Q4(1332±306) U12: Q1(1456±263) Q2(1481±315) Q3(1354±281) Q4(1441±266) U14: Q1(1805±285) Q2(1787±280) Q3(1784±374) Q4(1900±242) U16: Q1(2085±257) Q2(2170±280) Q3(2083±295) Q4(1976±311) U18: Q1(2308±285) Q2(2270±277) Q3(2308±270) Q4(2325±259)
Mendez-Villanuev, 2011	Middle East (Qatarian)	Elite	U14(12.7 ± 0.7), U16(14.9 ± 0.6), U18(17.0 ± 0.6)	U14(-1.7 ± 0.7), U16(0.4 ± 0.9), U18(2.2 ± 0.6)	N/A	N/A	U14(1.93 ± 0.11), U16(1.80 ± 0.06), U18(1.73 ± 0.06)	N/A	N/A
Reilly, 2000	European (English)	Elite and Non Elite	Elite (16.4) Non-Elite (16.4)	N/A	E(55.80 ± 5.82) NE (50.21 ± 7.58)	N/A	5m: E(1.04 ± 0.03), NE(1.07 ± 0.06) 15m: E(2.44 ± 0.07), NE(2.56 ± 0.12)	30m: E(4.31 ± 0.14), NE(4.46 ± 0.21)	N/A
Vadendriessche, 2012	European (Belgian)	Elite	U16(15.3 ± 0.3), U16F(15.2 ± 0.3) U17(16.2 ± 0.3), U17F(16.1 ± 0.3)	U16(13.6 ± 0.5), U16F(14.3 ± 0.5) U17(13.8 ± 0.5), U17F(14.9 ± 0.4)	U16(35.4 ± 3.5), U16F(30.9 ± 4.6) U17(36.3 ± 3.8), U17F(31.8 ± 4.4)	N/A	U16(1.817 ± 0.059), U16F(1.905 ± 0.079) U17(1.818 ± 0.083), U17F(1.878 ± 0.057)	U16(4.380 ± 0.155), U16F(4.630 ± 0.172) U17(4.332 ± 0.163), U17F(4.554 ± 0.163)	N/A
Towlson, 2017	European (English)	Elite	U13-U14: 13.8(95% CI: 13.6 - 13.9) U15-U16: 15.6(15.4 - 15.7) U17-U18: 17.8(17.6 - 17.9)	U13-U14: 14.1 (14.0 - 14.3) U15-U16: 14.2 (14.1 - 14.4) U17-U18: 14.9 (1.48 - 15.0)	U13-U14: 21.5(17.5 - 25.2) U15-U16: 25.8(21.8 - 29.8) U17-U18: 32.5(28.5 - 36.4)	N/A	U13-U14: 1.77(1.73 - 1.80) U15-U16: 1.64(1.61 - 1.68) U17-U18: 1.62(1.58 - 1.66)	**20m** U13-U14: 3.21(3.17 - 3.23) U15-U16: 2.96(2.92 - 2.99) U17-U18: 2.89(2.85 - 2.92)	**MSFT** U13-U14: 1910(1872 - 1947) U15-U16: 2181(2127 - 2234) U17-U18: 2383(2333 - 2433)
Vänttinen, 2010	European (Finnish)	Elite and Non-Elite	10 years, 12 years, 14 years	N/A	10Y(27.8 ± 4.2), 12Y(29.5 ± 3.4), 14Y(35.8 ± 4.2)	N/A	10Y(2.08 ± 0.07), 12Y(2.02 ± 0.05), 14Y(1.90 ± 0.9)	N/A	N/A
Vänttinen, 2011	European (Finnish)	Elite and Non-Elite	Group 1:10.8 ± 0.3 Group 2:12.7 ± 0.2 Group 3:14.7 ± 0.3	N/A	Group 1: 11Y(28.0 ± 4.7), 12Y(28.8 ± 3.6), 13Y(31.7 ± 4.7), 13Y(28.1 ± 3.1) Group 2: 14Y(30.2 ± 3.4), 15Y(34.1 ± 3.9), 15Y(35.1 ± 5.1) Group 3: 16Y(37.5 ± 4.7), 17Y(39.5 ± 5.5)	N/A	Group 1: 11Y(2.08 ± 0.07), 12Y(2.0 ± 0.08), 13Y(1.96 ± 1.0), 13Y(2.02 ± 0.05) Group 2: 14Y(1.93 ± 0.09), 15Y(1.86 ± 0.09), 15Y(1.91 ± 0.10) Group 3: 16Y(1.83 ± 0.10), 17Y(1.80 ± 0.12)	Group 1: 11Y(5.3 ± 0.21), 12Y(5.09 ± 0.20), 13Y(4.91 ± 0.25), 13Y(5.05 ± 0.16) Group 2: 14Y(4.80 ± 0.28), 15Y(4.56 ± 0.23), 15Y(4.64 ± 0.23) Group 3: 16Y(4.42 ± 0.23), 17Y(4.34 ± 0.25)	Group 1: 11Y(1768 ± 169), 12Y(1906 ± 253), 13Y(2134 ± 284), 13Y(1811 ± 348) Group 2: 14Y(2033 ± 327), 15Y(2121 ± 285), 15Y(2297 ± 321) Group 3: 16Y(2358 ± 283), 17Y(2348 ± 366)
Vaeyens, 2006	European (Belgian)	Elite and Non-Elite	12.2 ± 0.7, range 10.4–13.7	N/A		N/A			
Zubar, 2016	European(Swiss)	Elite, Subelite and Non-Elite	12.26 ± 0.29 Test1(12.27 ± 0.29), Test2(13.33 ± 0.29), Test3(14.33 ± 0.29)	N/A	T1(28.83 ± 3.73), T2(30.60 ± 3.76), T3(30.56 ± 3.80)	N/A	N/A	40m T1(6.64 ± 0.33), T2(6.43 ± 0.30), T3(6.21 ± 0.44)	T1(865.67 ± 284.81), T2(1087.57 ± 387.43), T3(1330.33 ± 456.79)

In order to make future comparisons with other studies tables 2 and 3 have been provided for both anthropometric characteristics and physical capabilities of youth footballers from differing nationalities, ethnicities and playing level. Although direct comparisons are not always possible it will give an indication of potential South African youth footballers strengths and weaknesses against other young players and their performance data.

1.2.8.2.4. Anthropometric Differences

Stature

Changes in stature are evident in general populations and the same applies for footballing populations (Rogol, Roemmich & Clark, 2002; Le Gall *et al.,* 2008). Whether affected by age or maturity status, older footballers have a significantly greater stature than younger individuals or those who had not experienced their PHV (Malina, Peña Reyes, Eisenmann, Horta, Rodrigues, & Miller, 2000; Le Gall *et al.,* 2008; Gravina, Gil, Ruiz,, Zubero, Gil, Irazusta, 2008; Wong, Chamari, Dellal, & Wisløff, 2009; Lago-Peñas, Casais, Dellal, Rey, & Dominguez, 2011; Rebelo, Brito, Coelho-e-Silva, Figueiredo, Bangsbo, Malina, & Seabra, 2012; Deprez, Buchheit, Fransen, Pion, Lenoir, Philippaerts, & Vaeyens, 2015; Hirose & Seki, 2015; Lovell, Towlson, Parkin, Portas, Vaeyens & Cobley, 2015; Towlson, Cobley, Parking & Lovell, 2018). Increased stature was present across nationality (Malina *et al.,* 2000; Hirose & Seki, 2015; Lovell *et al.,* 2015), ethnicity (Wong *et al*., 2009; Candhas, Silva, Chaves, & Portes, 2010; Hammami, Abderrahmane, Nebigh, Moal, Ounis, Tabka, & Zouhal, 2013) and playing level (Vaeyens, Malina, Janssens, Renterghem, Bourgois, Vrijens, & Philippaerts, 2006; Le Gall *et al.,* 2008).

Weight, Body Mass Index and Body Fat

Similar findings have been shown for increase in weight with older, and more mature, individuals experiencing greater weight gain than younger and prepubertal individuals (Malina *et al.,* 2000; Le Gall *et al.,* 2008; Gravina *et al.*, 2008; Wong *et al*, 2009; Lagos-Peñas *et al*, 2011; Deprez *et al*, 2015; Hirose & Seki, 2015; Lovell *et al.,* 2015; Towlson, Cobley, Parking & Lovell, 2018). Peak Weight velocity is an important milestone occurring approximately 18 months after PHV, and is the age many players experience an increase in physiological abilities (Rogol, Roemmich & Clark, 2002; Lloyd & Oliver, 2012). An increase in fat free mass occurs in youth footballers as body composition changes with hormonal development, thus any subsequent increase in mass is a result of muscle rather than fat (Malina *et al.,* 2000; Le Gall *et al.,* 2008; Wong *et al*, 2009; Lagos-Peñas *et al*, 2011; Vänttinen, Blomqvist, Nyman, & Häkkinen, 2011; Rebelo *et al*., 2012; Hirose & Seki, 2015; Lovell *et al.,* 2015; Towlson, Cobley, Parking and Lovell 2018), as discussed in section 1.2.8.4. A result of fat free mass increase is a decrease in BMI for both elite and non-elite populations (Malina *et al.,* 2000; Le Gall *et al.,* 2008; Wong *et al*, 2009; Lagos-Peñas *et al*, 2011; Rebelo *et al*., 2012; Hirose & Seki, 2015; Lovell *et al.,* 2015; Towlson, Cobley, Parking & Lovell 2018). Age and maturity related changes in body composition were consistent between playing level, (Malina *et al.,* 2000; Gissis, Papadopoulos, Kalapotharakos, Sotiropoulos, Komsis, & Manolopoulos, 2006; Le Gall *et al.,* 2008; Rebelo *et al*., 2012) nationality, (Malina *et al.,* 2000; Vänttinen *et al.*, 2011; Hirose & Seki, 2015; Lovell *et al.,* 2015) and ethnicity (Wong *et al*, 2009; Candhas *et al.,* 2010; Hammami *et al.,* 2013).

Physical & Physiological Development

How football specific physical and physiological attributes develop is of critical importance to players, coaches and administrators. Performance criteria can be adjudged in multiple ways with traditional maximal testing being one such method which has been widely covered in literature (Malina *et al.,* 2000; Gravina *et al.*, 2008; Le Gall *et al.,* 2008; Wong *et al*, 2009; Lagos-Peñas *et al*, 2011; Vänttinen *et al.*, 2011; Rebelo *et al*., 2012; Deprez *et al*, 2015; Hirose & Seki, 2015; Lovell *et al.,* 2015; Towlson, Cobley, Parking and Lovell 2018). Motion tracking technology has allowed more in-depth game analysis of the manner and rate in which the different distances and actions are completed (Carling *et al.,* 2008). Results from maximal testing batteries will be reviewed followed by motion analysis research, all through the paradigm of the performance effects brought on by maturation and age.

Maximal Testing

Maximal testing focuses on identifying key physical and physiological attributes from match play, and then evaluating performance using gold standard testing methodologies (Turner *et al*., 2011). Football specific testing batteries predominantly measure muscular strength and power (Comfort *et al.*, 2014; Peñailillo, Espíldora, Jannas-Vela, Mujika, & Zbinden-Foncea, 2016), acceleration and speed (Mendez-Villanueva, Buchheit, Kuitunen, Poon, Simpson, & Peltola, 2010; McCunn, Weston, Hill, Johnston & Gibson, 2016), agility (Mirkov, Kukolj, Ugarkovic, Koprivica, & Jaric, 2010; Lovell *et al.,* 2015) and cardiovascular output (Castagna *et al.*, 2010; Deprez, Vandenbulcke, Peeters, Emsell, Amant, & Sunaert, 2013). Each of these actions have been shown too positively influence the match outcome (Turner *et al.,* 2011). In addition, maximal tests have been shown to be valid in analysing sports specific capacities (Castagna *et al.*, 2010). However, this is a contentious issue with studies questioning the impact of various tests and their application to football (Mendez-Villanuava, Buchheit, Kuitunen, Douglas, Peltola, & Bourdon, 2011; Mendez-Villanuava & Buchheit, 2011). Consensus on how to measure each of these varies between studies making direct comparisons difficult, especially when dealing with different ethnicities, nationalities or playing level (Turner *et al.,* 2011). Nevertheless, the following areas have been investigated with similar findings attained, albeit with slight differences on testing methodology.

Strength has been evaluated with a variety of methods from one repetition maximum events to isokinetic testing (le Gall *et al.,* 2008; Carling *et al.,* 2009; Candhas *et al.,* 2010; Vänttinen *et al.*, 2011; Buchheit & Mendez-Villanueva, 2013; Peñailillo *et al.*, 2016). Vertical and broad jump are commonly used as power tests as they correlate well with general strength level (Turner *et al*., 2011). Vertical jump and broad jump have both shown that younger and less mature individuals are not able to reach the distance compared to older or more mature individuals (le Gall *et al.,* 2008; Carling *et al.*, 2009; Candhas *et al.,* 2010; Williams, Oliver and Faulkner, 2011; Vänttinen *et al.*, 2011; Buchheit & Mendez-Villanueva, 2013; Peñailillo *et al.*, 2016).

Acceleration and speed are well documented testing components within youth and adult football studies (Mendez-Villanueva *et al.*, 2011; Buchheit & Mendez-Villanueva, 2013; Comfort *et al.*, 2014). The difficulties arises with the various distances used to measure speed. According to Reilly *et al.* (2000) the highest sprint distance is 50m resulting in testing batteries measuring sprint time at distances below this value. This is corroborated by Cometti, Maffiuletti, Pousson, Chatard, and Maffulli (2001) who propose a sprinting distance of 10m and 30m to be adequate for maximal testing.

Ten meters is generally accepted as the optimal distance to measure acceleration (Wong *et al*, 2009). Differences are present between players of differing ages and maturities at this distance (Le Gall *et al.,* 2008; Carling *et al.*, 2009; Mendez-Villanueva *et al.*, 2011; Vänttinen *et al.*, 2011; Williams, Oliver & Faulkner, 2011; Rebelo *et al.,* 2012; Buchheit & Mendez-Villanueva, 2013; Hammami *et al.,* 2013; Comfort *et al.*, 2014;). Speed has also found differences in time between players of different ages and maturity level and this is consistent for distances of 20m (Le Gall *et al.,* 2008; Comfort *et al.,* 2014*;* Lovell *et al.,* 2015), 30m (Philippaerts *et al.,* 2006; Vaeyens *et al.*, 2006; Vänttinen *et al.*, 2011; Williams, Oliver & Faulkner, 2011; Hammami *et al.,* 2013) and 40m (Le Gall *et al.,* 2008). Again the implications of different ethnicities, playing level and training status make comparisons difficult but maturity has a positive affect on the acceleration and speed abilities of youth players (Vaeyens *et al.*, 2006; Lovell *et al.,* 2015).

Agility or change of direction testing is even more complex as the lack of consistency between testing batteries, brought on by the ambiguity in the definition of agility, has lead to a wide spectrum of tests being employed (Sheppard & Young, 2006; Turner *et al.*, 2011). Tests which have been used in football specific populations are as follows: Illinois Agility run, 5-0-5 (Rebelo *et al.,* 2012), 10m x 5 COD drill (Hirose & Seki, 2015) or T-test (Lovell *et al.,* 2015). As with strength, power, acceleration and speed, older and more mature individuals allowed had a greater level of improvement, with an additional factor being playing status (Philippaerts *et al.,* 2006; Vänttinen *et al.*, 2011; Rebelo *et al.,* 2012; Hirose & Seki, 2015; Lovell *et al.,* 2015).

Aerobic endurance has been evaluated in football playing populations through the use of incremental maximal tests such as the Multistage Fitness test (MSFT), Yo Yo Intermittent run (YYIR), or the Hoff Test (Castagna *et al.*, 2010). Each test determines a representative level of $\dot{V}O_2$ max which is a beneficial attribute footballers should possess in order to achieve success (Castagna *et al.*, 2010). Elite level footballers posses high values compared to non elite and this is consistent for youth footballers (Turner *et al.*, 2011). Individuals with greater peak uptake levels were more likely to be selected into academies therefore, more able to attain elite youth level competitions (Lagos-Peñas *et al.,* 2011; Deprez *et al.,* 2015). PHV is a positive variable on aerobic endurance ability and by connection age (Philippaerts *et al.,* 2006). Therefore, the older, more mature and more highly trained individuals produced greater $\dot{V}O_2$ max results (Philippaerts *et al.,* 2006; Figueiredo, Gonçalves, Coelho e Silva, & Malina, 2009; Vänttinen *et al.*, 2011; Deprez *et al.,* 2013; Hammami *et al.,* 2013; Deprez *et al*, 2015; Lovell *et al.,* 2015).

Motion Analysis

Global positioning satellites and motion tracking technology have allowed a more in-depth analysis of match play activity (Carling *et al.,* 2008). Information on in-game heart rate, running speeds as well as time spent and distance covered at a certain speed, total distance covered and the overall internal workload (Carling *et al.,* 2008). Motion analysis allows the comparison and potential correlation of maximal testing methodologies to be evaluated against in game activity and success (Carling *et al.,* 2008).

Care must be taken when interpreting results form motion analysis studies as differences in sprint performance must be relativised to game time and field size (Harley *et al.*, 2010). When results are relativised match play demands are similar among elite youth players between the ages of 12 and 16 years (Harley *et al.*, 2010). Between elite and non-elite players, elite level footballers achieved a higher absolute and relative workload (Strøyer, Hansen & Klausen, 2004; Harley *et al.*, 2010; Mendez-Villanueva, Buchheit *et al.,* 2011). However, elite players were classified as more mature than non-elite players (Strøyer, Hansen & Klausen, 2004; Harley *et al.*, 2010; Mendez-Villanueva *et al.,* 2011).

Overall, the impact of age and maturity on youth footballers has been well documented on a variety of physical and match play characteristics (Strøyer, Hansen & Klausen, 2004; Le Gall *et al.,* 2008; Carling *et al.*, 2009; Candhas *et al.,* 2010; Harley *et al.*, 2010; Vänttinen *et al.*, 2011; Williams, Oliver & Faulkner, 2011; Mendez-Villanueva *et al.*, 2012; Buchheit and Mendez-Villanueva, 2013; Peñailillo *et al.,* 2016). However, none of the studies indicated here have been conducted within a South African context.

<u>1.2.8.2.5. Technical</u>

Skill has been described by Bate (1996) as the 'learned ability to bring about pre-determined results from maximum certainty often with minimum outlay'. Ali (2011) outlined how skills can be broken down into two parts; open and closed skills. Closed skills are technical actions executed with the correct movements in a satisfactory manner with a prescribed pattern or outcome. Open skills refer to successfully replicating such closed skill actions during a game situation. Studies which have investigated technical skills associated with football - passing, shooting, crossing, controlling, dribbling, tackling and heading - utilise closed skill drills to describe a players technical ability.

For a technical action to be successful within a competitive environment a player has to assess a large amount of information and then execute the desired movement (Wilson *et al.,* 2016). Such actions require the involvement of physical, technical and cognitive abilities (Ali, 2011). Sequencing before an action takes place falls under the cognitive and tactical abilities of an individual, while technique and physical strength allow the execution (Ali, 2011; Wilson *et al.,* 2016).

Shooting is an important act in football and players should be proficient at shooting from a variety of distances and angles (Wilson *et al.,* 2016). Shooting involves hitting a targeted area from different distances, with points awarded for different targets, usually from static positions and requiring the use of both feet (Vaeyens *et al*., 2006; Wilson *et al.,* 2016).

A similar methodology is employed for passing drills, whereby a series of targets are arranged and participants are asked to accurately pass to them in a certain time or number of tries (Vaeyens *et al*., 2006; Vänttinen *et al.,* 2011; Wilson *et al.,* 2016). Juggling tests are also common among testing batteries although such a specific skill is not used in a competitive environment it does represent the level of control a player possesses (Ali, 2011; Wilson *et al.,* 2016).

Dribbling requires close control, quick changes of direction, acceleration and deceleration as well as awareness of opposing players (Wilson *et al.,* 2016). Testing of dribbling skills involves a prescribed course which players have to complete in the shortest time possible and with the least number of errors (Rosch *et al.,* 2000; Vaeyens *et al*., 2006; Wilson *et al.,* 2016). No closed skill test have been found for tackling, to the authors knowledge.

Shooting and passing comparisons between drills are difficult due to the varied testing set ups (Vaeyens *et al*., 2006). In game scenarios which require a variety of passes to be made with differing levels of pressure resulting in any standardisation of distance, and additional time, not reflecting how match situations occur (Ali, 2011). Dribbling has also not been accurately recreated within scientific studies (Ali, 2011). Without the presence of other players this drill has limited ecological value as reacting to defenders action is a key part of dribbling (Ali, 2011). Evidently, these tests do not reflect a game situation but can be good indictors of the basic techniques used in football. If players are unable to score highly on the afore-mentioned tasks than it is unlikely they will be able to replicate moves within high pressure situations. Thus, testing batteries with dynamic and unpredictable scenarios have been created to better differentiate abilities between footballers.

One open skill test is the Loughborough Soccer Passing Test (LSPT) along with the shooting version (LSST) (Ali e*t al*., 2007a). Both tests require the use of passing or shooting movements, control and dribbling to manoeuvre themselves to best respond to directions from an investigator (Ali *et al*., 2007a). As there are only four options within the LSPT this reduces the options available to a player and having no direct involvement from defenders results in limitations for the LSPT (Ali *et al*., 2007a).

Small sided games (SSG) are a viable alternative to static, closed skilled testing procedures (Fenner *et al*., 2016). Manipulating player numbers, pitch size as well as task constraints allows for a constantly varied and adaptable testing measure (Rampinini *et al*., 2007; Coutts et al., 2007; Hill-Haas, Coutts, Rowsell, & Dawson, 2008). Small sided games are valid predictors of physiological and technical ability which mimics full sided game responses (Jones & Drust, 2007). Adapting the team numbers and pitch size - to accommodate athletes of different ages and sizes - has shown to affect changes in on ball involvement and elicit different responses to both heart rate, RPE and work profiles (Rampinini *et al.,* 2007; Coutts et al., 2007; Hill-Haas, Coutts, Rowsell, & Dawson, 2008). Therefore, SSG is a useful tool to help distinguish talent level in youth footballers (Fenner *et al*., 2016). Games can be recorded and analysed, while the presence of qualified coaches allow evaluation of the technical ability of players using prescribed testing criteria (Fenner *et al*., 2016). Fenner *et al.* (2016) used evaluation criteria called the Game Technical Scoring Chart (GTSC) and validated it for the assessment of the influence of players in small sided games. The GTSC criteria are as follows: Cover for teammates, communication, decision-making, passing accuracy, first touch control, one versus one and shooting ability, any assists made, and marking of opposition players (Fenner *et al*., 2016). A potential drawback for SSG is the requirement of trained and qualified coaches to evaluate performance.

<u>Summary of Technical</u>

As discussed, the main problem with technical testing is the lack of intensity and unpredictability usually associated with competitive football matches. For elite players it is of little use to try and differentiate them on a series of closed skill drills, and the dynamic nature of youth development means singular testing sessions should not be relied upon. Closed skill testing is a snapshot methodology which provides only basic information on ability level, where the failure to perform adequately on such tasks indicates a skill deficit. The complexity in creating open skill testing has been documented and small sided games represent the best alternative.

1.2.8.2.6. Psychological

Although important in forming part of a holistic testing battery, the psychological domain was presently outside the scope of the current study due to ethical considerations.

1.2.8.2.7. Environmental, Organisational and Personality Contexts

Referring to Gagné's (2004) DMGT as a conceptual baseline the impact of chance is an unquantifiable aspect which will vary from situation to situation depending on the environmental and intrapersonal catalysts. The intrapersonal catalysts will determine a range of factors such as skill acquisition, motivation or response to setbacks (Gagne, 2004). The psychological, motivational and personality traits of an athlete are important factors in talent development (Morris, 2000). Elite athletes have significantly higher levels of motivation, confidence in their own abilities, better resilience and mental toughness in order to overcome obstacles, in addition to being less vulnerable to choking at critical junctures (Morris, 2000; MacNamara *et al.*, 2010; Forsman *et al.,* 2015; Honer & Feichtinger, 2016; Li, Wang, & Pyun, 2014; Rees *et al.,* 2016). Such personality traits are evident across multiple sports, in both sexes and at varying ages indicating successful elite athletes share a psychological profile (Rees *et al.,* 2016).

The physical, cultural, social and familial milieu are all environmental catalysts (Gagne, 2004). Optimal environmental catalysts will provide support and create adequate organisational structures to enhance talent development (Gagne, 2004). Geographical or socio-cultural influences (Côté, Macdonald, Baker & Abernathy ,2006), climate availability and seasonality (Bergeron *et al*., 2015), provision of resources (Rees *et al*., 2016), family size, support and socio-economic status (Côté, 1999; Gagne, 2004; Rees *et al.,* 2016) are all important factors. In footballing terms, the organisational structure - either team or governing body - has considerable influence on a youth athlete. Team organisation involves the availability of good facilities, supportive and skilled coaches (Martindale, Collins, & Daubney, 2005; Bergeron *et al*., 2015) and a productive working environment (Relvas, Littlewood, Nesti, Gilbourne and Richardson, 2010).

1.2.9. Contextualisation of the South African and Study Setting

There are many unique circumstances which occur in South Africa, requiring additional explanation of the current socio-economic environment as well as issues around the organisational problems present in the South African Football Association (SAFA). In doing so greater context can be given to the results with further analysis framed within the national constraints.

1.2.9.1. South African Socio-Economic Environment

The socio-economic environment many youth athletes contend with in South Africa is not one conducive to developing talented athletes. The quadruple burden of disease relates to the impact of HIV/ Aids, non-communicable diseases, communicable diseases and injuries, namely the high level of violence present in South Africa (Pillay-Van Wyk *et al*., 2017). Additionally, the wealth distribution in South Africa is highly unequal with the Gini coefficient, a measurement of wealth dispersal, indicating a poor distribution (Pillay-Van Wyk *et al*., 2017). Therefore, the potential socio-economic situation of individuals situated in Makhanda/Grahamstown, Eastern Cape will be discussed to present a more holistic understanding of possible barriers an individual may encounter.

The 2011 Census described the Makana Municipality as having approximately 80,000 residents, with 78% of residents being classified as black with a further 12% as coloured and 9% white. Age distributions in the Makana region are skewed towards a more youthful demographic, with a quarter of the population being under the age of 14 and half being under the age of 24. In terms of potential talent pool there are approximately 13,600 males under the age of 18. There are 21,000 households on record with 85% being classified as formal dwellings. Almost 9000 of these households are female headed indicating a high proportion of single parent families. An asset indicator has been used to classify socio-economic status in previous South African studies.

Further, the 2011 Census outlines the high level of unemployment in Makhanda in conjunction with poor school pass rates. Nearly 13% of the population have no documented income with a further 4.2% earning less than R4800. In total, approximately 58% of Makhanda residents earn less than R3200 ($248) a month with this value representing minimum wage. Youth Unemployment (15-34) is 43% and worryingly only 11% of the population has completed secondary school.

National Health Report and findings

The National Health Report outlines how a high level of sugar consumption and fast food intake resulted in F grades. In combination, fruit and vegetable intake along with food security were rated as D grades (Uys *et al*., 2016). This is in large part due to high levels of unemployment and the rising cost of food, along with poor access to high quality foods (Uys *et al*., 2016). As the report states this has resulted in young individuals consuming a diet “lacking in dietary diversity, high in starchy foods and low in fruits and vegetables” (Uys *et al*., 2016). Such scenarios increase the risk of stunting and malnutrition which would significantly impact on physical performance (McVeigh, Norris & de Wet, 2004; Monyeki *et al*., 2006; Kruger & Pienaar, 2009; Pienaar & Viljeon, 2010; Jacobs & De Ridder, 2012; Toriola, Monyeki & Toriola, 2015; Armstrong, Lambert & Lambert, 2016).

A lack of parental support for South African children for participation in physical activity programs resulted in a C- grade, and combined with the same grade for influence of the community and build environment (Uys *et al*., 2016). These both reflect the lack of support parents are able to afford to their child through either monetary or parental support and the lack of resources present in many communities (Uys *et al*., 2016).This is a simple example of the potential problems affecting South Africans. It speaks to the poor socio-economic levels present within society and its impact on youth individuals health. Elite athletic attainment requires healthy individuals being supported in all aspects of their life. The extent to which each socio-economic problems impact on a South African youth footballer has not been fully investigated.

1.2.9.2. Organisation & Structure of South African Football

Football has a large popularity in South Africa with FIFA's Big Count (2006) concluding the country has the 4th most players worldwide. The accuracy of such reporting may be questionable, but it does highlight the potential number of players within South Africa. The Technical masterplan (SAFA, 2012) also indicates roughly 3 million participate in South African football.

In reviewing the structures of both youth and professional leagues, the access and quality of coaching present, future plans for youth development, status of elite players and the infrastructure available, a more complete understanding of where problems might be present in preventing talented youth athletes from being developed. All information is taken from yearly SAFA reports and from the SAFA Technical Masterplan which was created in 2012 to provide a path forward for South African football.

1.2.9.2.1. Structure of Leagues and Teams

The current structure of the South African football league comprises of two professional divisions followed by a semi-professional provincial division and then regional and local amateur leagues, as evident by Figure 4 (SAFA Technical Masterplan, 2012).

The Premier Soccer League (PSL) contains 16 clubs, while the National First Division has the same amount (SAFA Technical Masterplan, 2012). The Premier Soccer League has the largest sponsorship and television deal in comparison to other African leagues SAFA (Technical Masterplan, 2012). Furthermore, the level of total sponsorship for the PSL puts it on even footing with certain European and overseas football leagues. The current wages do not match those of their European counterparts but for certain elite South African players a good standard of living can be achieved (FIFPRO Global Employment Report, 2016). However, nearly 60% of players based in South Africa players, earn less than $1000 a month (FIFPRO Global Employment Report, 2016). Thus the expectation versus the reality of becoming an elite footballer can become two very different outcomes.

Provincial leagues consists of nine leagues each with 16 clubs for a total of 144 teams (SAFA Technical Masterplan, 20§12). 52 Regional leagues represent the division below with an estimated total of 832 clubs (SAFA Technical Masterplan, 2012). At local level, SAFA estimate 380 LFAs are in existence but only 200 functioning leagues with 16-20 teams in each league (SAFA Technical Masterplan, 2012). A total of 5216 teams, although further evidence is needed to substantiate such figures.

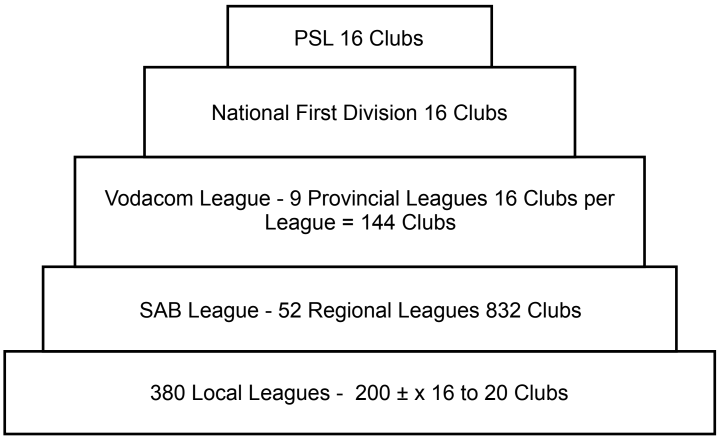


Figure 4: League structures as defined by the SAFA technical master plan (2012)

SAFA introduced the first fully functioning regional youth leagues (Under 13 and U15) in the 2012/2013 season (SAFA Technical Masterplan, 2012). The Under 17 leagues commenced in 2013/2014, with the Under 19 league beginning the following season (SAFA Technical Masterplan, 2012). SAFA mandates each club should have an Under 13,15,17 and 19 year old teams as part of its structure (Technical Masterplan, 2012). Previously, a reliance on regional, provincial and national cup competitions was the main formant used (SAFA Technical Masterplan, 2012). Additionally, a grassroots development program has been established to help introduce players between the ages of 6-12 to the game (SAFA Technical Masterplan, 2012).

1.2.9.2.2. Present Infrastructure

A lack of facilities is present within South African football and there is a need for government help in rectifying this issue. At least one 5000 seater stadium per province is planned but this has not come to fruition (SAFA Technical Masterplan, 2012). The geographical proximity between clubs in a both local and regional leagues has resulted in difficulties when deciding where to construct new playing fields (SAFA Technical Masterplan, 2012). An attempt to produce 52 fields in all 52 regions but this is a small number especially when considering team or player to field ratio (SAFA Technical Masterplan, 2012). The training of administrators, which is a major concern in South Africa, is also required. Input working office and internet connection to better monitor players which so far have been lacking (SAFA Technical Masterplan, 2012). Establishing regional academies and LFA centres for development has been planned but without trained administrators and coaches this will be a difficult task (Technical Masterplan, 2012).

1.2.9.2.3. Coaching Levels & Development

South African coaching education and syllabus has undergone significant transformation in the preceding 20 years (SAFA Technical Masterplan, 2012). Coaching education and coaches are viewed as the bedrock of future success for South African Football (SAFA Technical Masterplan, 2012). The main concern is the quantity of coaches coming through, especially for the professional licence badges (Technical Masterplan, 2012). Since 1996 South Africa has consistently struggled to provide enough coaches to meet demand (Technical Masterplan, 2012). The SAFA Technical Masterplan (2012) established the desired ratio of coaches to players as being 1:20, based on having 3,000,000 players in the country with this requiring a further 150,000 more trained coaches. A breakdown of how this number will be achieved is provided in Table 4. When comparing the average number of coaches trained in preceding years to the minimum number desired it may be a difficult challenge to complete (Coopoo *et al.*, 2012).

Worryingly, a majority of qualified coaches - 88.7% as of 2009/2010 - have come from the introductory course (SAFA Technical Masterplan, 2012). As a result the level of technical and tactical ability will be affected if players are unable to receive appropriate coaching (Coopoo *et al.*, 2012). Models of talent development have stressed the importance of coaching on improving youth players (Rees *et al.,* 2016). The most common reason supplied for the lack of coaches is funding (Coopoo *et al.*, 2012). Issues around SAFA being able to organise coaching badges as well as the poor financial health of many local associations (SAFA Technical Masterplan, 2012). The burden of the lower coaching badges is often placed on these associations where financial stability has been a constant concern (SAFA Technical Masterplan, 2012).

Table 4: Breakdown of coaches to be trained (SAFA Technical Masterplan, 2012)

	Courses a year	Participants per course	Number of Years	Total Coaches Trained
Pro Licence	1	20	10	200
A Licence 2013/17	9	30	5	1350
A Licence 2018/22	18	30	5	2700
B Licence 2013/17	53	30	5	7950
B Licence 2018/22	106	30	5	15900
C Licence 2013/17	600	20	5	60000
C Licence 2018/22	900	20	5	90000
Total				178100

1.2.9.2.4. Overview of Elite Players Abilities and Testing Procedures

Within the SAFA Technical Masterplan (2012), is the outlined philosophy of how SAFA would like the national team to play. The finer tactical points are of little relevance to this thesis but certain individual attributes are discussed. Several important points are raised, as supported by Coopoo *et al.*, (2012) demonstrating the limitations of South African players.

The SAFA Technical Masterplan (2012) describes players as having grown up in challenging social and educational environments which involved a lack of financial and parental support. Players are strongly influenced by the media, while the role or importance of money and status is exaggerated. Player's will often possess good raw skills with the ball with excellent creativity, flair and dribbling skills along with an innovative style of play, However young South African players are inexperienced in using tactical behaviour patterns and lack experience in learning new tactics. Players will have the desire to succeed but are behaviourally undisciplined in terms of their diet and learning. Self centred with egotistical behaviour is commonly found with players often lacking professionalism and discipline in their preparation for matches and training, however many players are resilient to setbacks. A recurring problem is the lack of physical strength exhibited by South African footballers.

The first characteristic needed to be measured in the SAFA Technical Masterplan (2012) is endurance with a multistage fitness test being recommended. Isokinetic dynamometry is presented as the measure of choice for strength. Although this is the gold standard of strength testing, it is recognised as being an expensive piece of machinery. This makes it less feasible when measuring players from remote areas within the country. Distances of 5, 20 and 40 meters are set to measure acceleration and speed, with times of 1.05, 2.9 and 5.2 seconds recommended as benchmarks. Speed Endurance should be measured by the repeated anaerobic sprint test with a drop of no less than 10-12% considered optimal. The 5-0-5 drill for agility should be used to identify players abilities with a time of less than 2.2 seconds. No evidence or reasoning is given as to why these times are selected with values not being based on youth South African data.

1.2.9.2.5. Youth Development Structures & Plans

The SAFA Technical Masterplan (2012) advocates for the Long Term Athletic Development mode in nurturing talent as outlined in section 1.2.6.5. Attempts to establish local, regional and provincial talent identification and development structures are detailed to provide appropriate coaching to youth players within the LTAD framework. SAFA outline the 6 tests which are recommended for identifying youth players with a 20m sprint, agility run, dribbling, ball control including passing, shot on goal and juggling. Data would be used to establish national averages and provided feedback on an individuals development. However, no statistics can be found to this authors knowledge.

The research report by Coopoo *et al*. (2012) is a detailed analysis of the current problems in South African youth football. Key findings include problems with the management, administration, financial support, poor socio-economic status and a lack of exposure to sport science for youth athletes. A lack of investment - with total funding from SAFA being 30% of their overall budget - means the naturally talented and gifted players are not being adequately developed. A win now attitude is also present leading to the overtraining or exclusion of players to achieve immediate results. A lack of qualified youth coaches was further substantiated by the report, with no coaches having any long term monitoring systems in place. Additionally, coaches are expected to take on multiple roles which they were not trained for and is indicative of a lack of resources available for the majority of teams in South Africa.

1.2.9.2.6. South African Footballing Research

There is currently a lack of research involving South African players. Below is a list of the conducted research, its population sample and the domain of interest. The wide diversity and focus of the research has meant a lack of coherence between studies.

Table 5: South African specific football research

Study Authors and date	Population	Domain of interest
Zeederberg et al. (1996)	Amateur (under 19)	Nutrition
Nematswerani *et al.* (2005)	Professional players	Injury
Clark$_{a,b}$ (2007)	Professional players	Physical performance
Bailey *et al.* (2009)	Amateur (urban poor)	Performance and physiological characteristics
Du Randt (2009)	Professional	Physical characteristics
Rebelo *et al.* (2010)	Professional, semi-professional and amateur (University)	Physical characteristics
Goedeke et al. (2013)	Amateur (LFA)	Nutrition
Aginsky et al. (2014)	Professional	Physical characteristics
Calligeris et al (2015)	Professional	Injury
Gordon et al. (2015)	Amateur (urban poor)	Physiology
Jones et al (2015)	Amateur (university)	Physiology
Sparks (2016)	Amateur (university)	Physical characteristics
Starzac et al (2016)	Youth (low socioeconomic status)	Immunology

As viewed in Table 5, there is limited research on South African footballers, especially on youth players.

Only three studies, to this authors knowledge, have been conducted on youth South African footballers. Starzak, Konkol and Mckune (2016) investigated the effects of soccer specific training on various neuro-endocrine responses and will not be discussed due to lack of transferable information. Gordon, Kassier, & Biggs (2015) determined the hydration status of youth underprivileged football players and found that nearly a quarter of players were severely dehydrated. This serves to highlight the lack of knowledge and access to resources as characterised by low socio-economic areas. Finally Coopoo and Fortuin (2012) identified the lack of well structured training programs and appropriate sport science techniques being utilised by youth development programs. A lack of weight training, testing sessions, access to a doctor or medical professional before or after injury occurs as well as a lack of nutrition provided to youth players (Coopoo & Fortuin, 2012).

1.3. Problem Identification

The review has detailed how talent development systems should operate in order to develop elite youth footballers. Successful youth development models requires the constant monitoring of maturity and specific anthropometric, physical, tactical, cognitive and personality characteristics and abilities. How such components develop, in terms of their rate, tempo and timing are important to understand for the appropriate training can be administered.

Many basic characteristics of youth South African footballers are not documented and need to be outlined in greater detail. The lack of research on youth South African footballing populations has resulted in a dearth of knowledge on basic ability level. This is particularly the case outside of the large metropolitan areas of the country and in provinces like the Eastern Cape. Without such information the possible barriers and limitations preventing elite footballing talent from being produced are unknown. When factoring in the unique socioeconomic context within the country, possible constraints can be an additional hinderance when producing talented youth footballers. Thus, to provide a base for future research the current thesis will focus on the influence of age and maturity on the anthropometric characteristics and physical capabilities of youth footballers participating in the LFA structures of SAFA based in Makhanda/Grahamstown, South Africa.

CHAPTER II: METHODS

2.1. Experimental Design

The purpose of the current study was to quantify the anthropometric and physical characteristics across four age groups, along with five different maturity groups, of players from the Eastern Cape province of South Africa. More specifically to look at players in the Sarah Baartman region, playing football in Makhanda/Grahamstown in the official LFA league structures of SAFA. In order to fulfil this purpose a two-factorial study design was developed to investigate age and maturity effects. Each participant had to complete the two component batteries with age and maturity stratification being implemented (Table 8 & 9).

Table 6 A & B: Different age (A) and maturity (B) groups along with the tested dependent variables.

A)

UNDER 11	UNDER 13	UNDER 15	UNDER 19
ANTHROPOMETRIC CHARACTERISTICS, PHYSICAL ABILITIES	ANTHROPOMETRIC CHARACTERISTICS, PHYSICAL ABILITIES	ANTHROPOMETRIC CHARACTERISTICS, PHYSICAL ABILITIES	ANTHROPOMETRIC CHARACTERISTICS, PHYSICAL ABILITIES

B)

PRE24	PRE12	MATURITY OFFSET	POST12	POST24
ANTHROPOMETRIC CHARACTERISTICS, PHYSICAL ABILITIES	ANTHROPOMETRIC CHARACTERISTICS, PHYSICAL ABILITIES	ANTHROPOMETRIC CHARACTERISTICS, PHYSICAL ABILITIES	ANTHROPOMETRIC CHARACTERISTICS, PHYSICAL ABILITIES	ANTHROPOMETRIC CHARACTERISTICS, PHYSICAL ABILITIES

The anthropometric characteristics and physical abilities for both maturity and age groups are detailed below in greater depth, section 2.3.

2.2. Selection of Independent Variables

2.2.1. Age

Age related differences, and the extent to which they differ, in the anthropometric and physical domains were the main focus of this thesis. By quantifying the differences relative to age and the potential development curve would indicate the characteristics of youth South African footballers. As identified in the review of literature (see sections: 1.2.7 & 1.2.8) age-related factors are very important in the development of youth athletes and in particular football players. Development is not a linear pathway and effort must be made to understand the individual context. Consequently, age was deemed as an important independent variable in the current study. Ages were split into Under 11, 13, 15 and 19 as this represents age groups used in the Makhanda LFA for junior competitions.

2.2.2. Maturity

Research, section 1.2.7, has shown the impact of maturity on sporting performance to be of critical importance when distinguishing between the ability level of youth athletes. The maturational development of youth South African footballers is currently not documented and this may have an impact on how youth development is being conducted. The maturity spread - the rate, timing and tempo an individual experiences maturity - will differ between athletes and the impact of this on anthropometric characteristics and physical abilities is required. Therefore this was deemed as a salient research objective for the current study and was included as an independent variable. Maturity bands were selected to showcase the adaptations the body experiences throughout the pubertal process. Stratification was done in 5 groups with the first being individuals 24 months away from their maturity offset (MO), then individuals between 24 and 12 months of their maturity offset, individuals within a year or experiencing their maturity offset, players between 12 and 24 months past their MO, and finally individuals who are more than 24 month past their maturity offset. These groups are expressed as PRE24, PRE12, MO, POST12 and POST24 respectively.

2.3. Dependent Variables

2.3.1. Anthropometric Variables

Several anthropometric variables were deemed as being important for consideration in understanding soccer performance. Different positions require different anthropometric profiles due to the unique demands of each position (Strauss *et al.,*2012).

This is particularly pertinent in the SA context where the understanding of these variables in urban poor soccer players is scarce. Therefore the following anthropometric variables formed part of the investigation:

- Stature (mm)
- Body mass (kg)
- Body composition (including percent body fat and lean body mass)
- Body Mass Index (kg/m^2)
- Peak Height Velocity

2.3.2. Physical Variables

The physical demands of football are well established and consequently numerous physical attributes are important for understanding the level of performance in youth footballers. For the current study the following were considered as relevant and important:

Table 7. The different physical dependent variables along with the tests used to measure.

Physical Component	Test
Aerobic Capacity	Yo- Yo Intermittent Run
Acceleration	10m Sprint
Speed	30m Sprint
Power	Vertical Jump
Agility	Illinois Agility Run

2.3.2.1. Aerobic Capacity

As highlighted in the review of literature high aerobic capacity is a fundamental component to posses if an athlete wishes to be successful in a given sport, particularly so for football. Peak oxygen uptake was deemed as an important variable for this study and efforts to accurately measure capacity in a manner which reflected the demands of a football match were conducted.

The Yo-Yo Intermittent Recovery *(YYIR)* run has been found to be a reliable and validated measure of aerobic capacity and $\dot{V}O_2$ max (Turner *et al.,* 2011). It has been used in a variety of football studies for both youth and adult populations (Turner *et al*., 2011). There are two different versions namely the YYIR level 1 and YYIR level 2. Level 1 is for younger athletes who do not yet have the cardiovascular capabilities to complete Level 2. The YYIR has also shown differences between elite and non-elite groups indicating its usefulness in talent identification. Therefore the YYIR level 1 was used in the current study.

2.3.2.2. Acceleration and Speed

Acceleration has been predominantly measured over 10 meters and was therefore the distance used for testing (Carling *et al.,* 2009). Speed was slightly more varied with different studies measuring distance over 20m (Carling *et al*., 2009), 30m (Malina *et al.,* 2004) and finally 40m (le Gall *et al.,* 2008). For this study, a distance of 30 meters was selected due to its repeated occurrence in football matches and TID studies. Furthermore, nearly 96% of sprints in football are less than 30m thus footballers should not be expected to sprint much further (Bangsbo, 1994).

2.3.2.3. Power

Power movements are utilised in sports such as football for a variety of movements such as jumping, kicking, throw-ins and tackling (Granacher *et al.,* 2016). There is a positive relationship between strength testing events, such as 1 repetition max squats, and activities such as countermovement and vertical jumps (Turner *et al*., 2011). Therefore, squat jumps and countermovement jumps were used to measure power output. These tests have been shown to be reliable and valid for measuring lower body power output in footballers of a variety of ages (Turner *et al*., 2011).

2.3.2.4. Agility

Agility utilises acceleration, change of direction, top speed attainment and deceleration mechanisms in order to be successful (Sheppard & Young, 2006). Thus, agility is defined as “a rapid whole-body movement with change of velocity or direction in response to a stimulus” (Sheppard & Young, 2006, p. 160).

Agility testing is far from uniform with the reliability and validation of different tests still not rendering conclusive results. Many of the tests have been used extensively to measure change of direction (COD) rather than agility, thus reducing their impact (Young *et al*., 2015). In conjunction there is a lack of longitudinal data indicating which test is a better identifier of talented athletes. However, the Illinois agility run has been used in football studies and has shown differences between elite and non-elite level players (Turner *et al*., 2011). The Illinois agility run should rather be classified as a COD test, but the subsequent lack of a valid agility test means it was the best option and was therefore used in the current study.

2.4. Equipment

2.4.1. Anthropometric characteristics Equipment

A stadiometer *(Veeder-Root. Elizabethtown, U.S.A.)* was used to measure the stature of the players and a scale *(Model: Toledo Scale corp. type no. 8142)* was used to measure their weight. Skin fold callipers (*Model: HaB Direct, SKU: LHSC-C, Warwickshire, United Kingdom*) were used to measure the participants skin fold body fat at specific sites to allow the determination of lean body mass and total fat percentage. A 1m ruler was also used to measure Peak Height Velocity to determine an individual maturity status.

2.4.2. Physical Characteristics Testing Equipment

To measure acceleration and speed, timing gates *(Brower Timing Systems, Utah, U.S.A)* where used. Gates were placed at the start, at 10m and at the 30m finish line to get the precise time for each participant.

A Vertical Jump Board was used to measure the power of each participant by seeing how high they can jump from a stationary position. Participants were asked to stand next to the Vertical Jump Board, raising their dominant hand to reach up and touch the highest point possible while keeping both feet flat on the floor. This is the standing reach height and once this point was measured participants were then allowed to complete the jump. Players were allowed a countermovement and tried to achieve the maximum height possible.

The setup for the Yo-Yo Intermittent Recovery Test involved setting out two rows of cones, Row B and C, at a distance of 20m with a 5m recovery zone between Row A and B. A downloaded version of the Yo-Yo intermittent run was administered through portable speakers with participants asked to follow the instructions. Players started running on the first beep and had to cover the 20m to Row C before the next beep. Once the beep sounded players returned to Row B before the final signal occurred. The pace increased, while the time allowed to complete a 20m run decreased, as the test progressed.

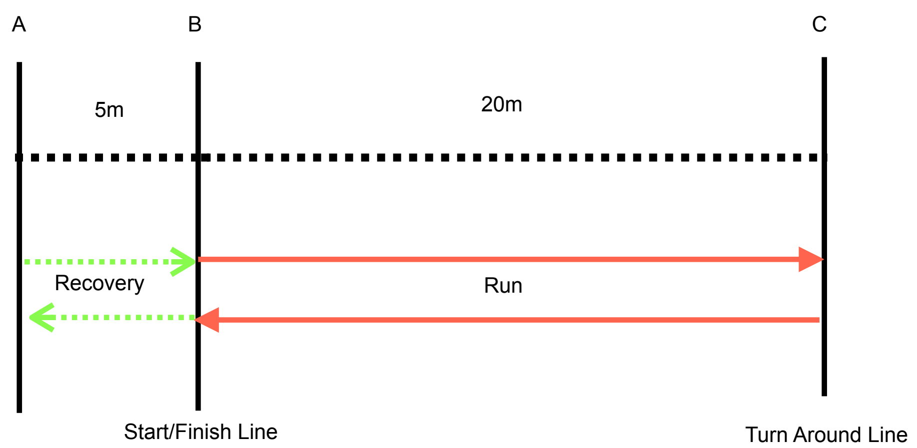


Figure 5. Graphical representation of the Yo-Yo Intermittent Recovery Test

2.5. Participants

Players were recruited from local youth academies and teams within Makhanda/ Grahamstown. More specifically the players were recruited from clubs that participate in the local football association leagues. As such the players represent the clubs in the official SAFA league responsible for TID making it important to quantify their current characteristics. Players competed in the local youth structures beginning at Under 11 up to Under 19. A breakdown of participant numbers can be viewed in Table 8 and 9. Other characteristics of the participants included ethnicity, sex, socioeconomic status, and footballing experience and these are explained in greater depth, page 66-67 .

2.5.1. Age & Maturity

Participants were from a number of age ranges in order to assess the rate of adolescent development in the selected sample. The age groups were stratified accordingly: Under 11, 13, 15 and 19. These groupings were used as they reflect the age based grouping system used by SAFA for youth leagues. Under 11's would not have gone through puberty yet while Under 13 represents those who had either started or had yet to experience their peak height velocity (Rogol, Roemmich, & Clark, 2002). Under 19's represented the final age before players transitioned into adult level competition age (Rogol, Roemmich, & Clark, 2002).

Table 8: Number of Participants and average age per each age group.

Age Group	Number of Participants	Average Age (Years)
Under 11	40	10.9
Under 13	45	12.7
Under 15	22	14.4
Under 19	29	18.1
Total	136	14.03

Maturity was also considered as this has shown to have an effect on youth development. Peak Height Velocity has been shown to be a non-invasive validated measurement of biological maturity (Mirwald *et al.,* 2001; Philippaerts *et al.,* 2006). Groupings were described as individuals greater than 24 months from PHV, between 24 and 12 months to PHV, between 12 months from and 12 months past PHV, 12 to 24 months past PHV and finally individuals who had experienced their PHV at least 24 months prior.

Table 9. Participant Numbers, Chronological Age, Maturity Onset and Age of Peak Height Velocity.

Maturity Group	Number of Participants	APHV (Years)	Maturity Offset (Years)	Chronological Age (Years)
PRE24	34	14.31	-2.84	11.47
PRE12	21	14.45	-1.57	12.89
MO	16	14.66	-0.14	14.54
POST12	10	15.85	1.7	17.52
POST24	15	15.71	2.82	18.54
Total	96	14.78 (±0.99)	-0.75 (±2.19)	14.03 (±2.85)

2.5.2. Sex

Only males were considered for this thesis as the lack of availability of female soccer players resulted in it not being viable to include them. Although it is important to gain more knowledge about the development of youth Black females - in terms of sporting ability - it was not a focus for this study.

2.5.3. Socioeconomic Status and Demographic Information

The socioeconomic (SE) status of soccer players in the local leagues had not been established. SE status may have an impact on the physical development of young athletes; therefore it was important to acknowledge such a factor (McVeigh *et al.,* 2004). Therefore, socioeconomic status was included as an important variable in the current study. In order to establish SE status a questionnaire was administered, as seen in Appendix A.7, which asked for monthly income as well as the number of family members supported by that income. How participants got to school was also useful information which was required. The questionnaire was based on the Statistics South African General Household Survey (2014).

Demographic information on Race, Home Language as well as basic schooling information were included. What grade players were in could then be tallied with their current age to better understand their schooling progress, while potential reasons for not being in school before completing Grade 12 .

2.5.4. Footballing Experience

Participants had to have at least two years football experience. A questionnaire detailing their football history was administer before testing began to ascertain current and past playing status (Haugaasen & Jordet, 2012). Anyone not having the prerequisite years experience was excluded from the study. The age a player started playing and the number of years they had been playing was asked, as evident in Appendix A.7.

2.6.Protocol

2.6.1. Ethical Considerations and Recruitment

Prior to the experimentation, approval for conducting this research was obtained from the Human Kinetics and Ergonomics Ethics Committee (Appendix B.2) as well as the Rhodes University Ethics Committee (Appendix B.1.). 163 participants in total were initially recruited via their soccer coaches with interested participants being given a letter of information (Appendix A.1.) and a parental consent form (Appendix A.3.). Once the participants and their parents or guardians had signed the consent form they were requested to attend 2 different testing sessions.

2.6.2. Introduction Session

The first session, which lasted approximately 30 minutes, was used to recruit and inform participants with what was expected of them, as well as the risks and benefits of participation in the study. Ethical considerations such as their right to confidentiality and anonymity, and the option to withdrawal voluntarily were also referred to. Participants were given the opportunity to ask questions after an overview of the study and each component had been given. In addition, the demographic, socio-economic and footballing history questionnaire was given out for completion. Players took the consent form home to be completed and collected again before the first testing session.

2.6.3. Experimental Sessions

The second session focused on collecting anthropometric data and conducting the physical testing battery.

Anthropometric Data Collection

Anthropometric data included measurement of stature (mm), weight (kg), lean body mass and peak height velocity. Lean body mass was determined by using a skin fold calliper to measure total body fat in percentage points. Sites of measurement included the tricep and sub-scapular (Slaughter *et al*., 1998). Participants were asked to remove their shirts to provide ease of access to the necessary sites of measurement. The equations, as taken from Slaughter *et al.* (1998), were:

- Prepubescent Black Males = 1.21(triceps + subscapular) - 0.008(triceps + subscapular)^2 - 3.2
- Pubescent Black Males = 1.21(triceps + subscapular) - 0.008(triceps + subscapular)^2 - 5.2
- Postpubescent Black Males = 1.21(triceps + subscapular) - 0.008(triceps + subscapular)^2 - 6.8

Peak Height Velocity was found using date of birth, weight (kg), standing height (mm) and sitting height (mm). First stature, to the nearest mm was taken using a stadiometer. The stretch stature method was utilised to ensure adequate technique was maintained. Participants stood barefoot, feet together with their back, buttocks and heels up against the stadiometer. The participants head was placed in the Frankfurt plane, as the vertex was placed atop their heads. Participants were asked to take a deep breath and the measurement was taken at the end of breath.

Following this weight was measured to the nearest 0.1kg, with two readings for each participant taken. Participants were asked to remove any heavy items of clothing, such as shoes or jerseys with only lightweight clothing - shirts and shorts - being permissible.

Finally participants were asked to sit upright on a table with hands resting on their laps. Participants were placed in the Frankfurt plane once again with care was taken to ensure players didn't contract gluteal muscles to add additional height. A 1m ruler was used to measure the distance from the top of the table to the vertex of the head. Two readings, values had to be within 0.4cm of each other, were taken to ensure an accurate measurement had occurred. All formulas to calculate PHV were taken from Mirwald *et al.,*(2001). The Mirwald *et al*., (2001) maturity Offset equation utilised was as follows: (-9.236 + 0.0002708 x Leg Length and Sitting Height interaction) + (-0.001663 x Age and Leg Length interaction) + (0.007216 x Age and Sitting Height interaction) + (0.02292 x Weight by Height ratio).

<u>Physical Data Collection</u>

The physical testing battery consisted of 4 different sections. These were aerobic capacity, acceleration and speed, power and agility. Each player was given a demonstration of each physical test with an opportunity to walk through the test as a means of familiarisation. Each player was provided with 3 attempts, with the average value used for each test apart from the Yo-Yo Intermittent Recovery run which was conducted once. An extended 15 minute warm up was conducted before participants attempted the test battery. The warm up included dynamic stretching of the legs with the quadriceps, hamstrings and groin being of particular importance, as well as sprints of 10, 20 and 30m at half and three quarter pace. All tests were supervised by the author along with several experienced colleagues.

The order of tests below was the order participants completed the battery, as per sports field testing guidelines (Turner *et al*., 2011).

- Power was measured using the vertical jump test. Players were required to perform a maximal jump in an attempt to reach the highest point possible.
- The Illinois agility run is a validated measure of agility. Each participant had to complete the set course in the shortest time. The course consisted of a number of changes in direction and movements had to be correctly executed for the time to count.

- Acceleration and speed consisted of a 10 and 30-meter sprint with timing gates positioned. Each footballer had to complete the sprint in the shortest time possible.
- Aerobic capacity was tested using the Yo-Yo Intermittent Recovery (YYIR) run. All players completed the YYIR Level 1.

2.7. Data Analysis

2.7.1. Statistical analysis

The statistical package R was utilised for all statistical procedures in the current study. Tests for homogeneity of variance (Bartlett K-squared) and normality (Shapiro-Wilks) were conducted.

Hypothesis for both were as follows:

H_0: $\sigma_1^2 = \sigma_2^2 = \ldots = \sigma_k^2$

H_a: $\sigma_1^2 \neq \sigma_2^2 \neq \ldots \neq \sigma_k^2$

If H_0 was accepted for the Shapiro Wilks test than a one way analysis of variance (Anova) was utilised. If H_0 was rejected then the Kruskal-Wallis (KW) one way analysis of variance was conducted. For normally distributed data Tukey's Honest Significant Difference (HSD) test was used to compare means post-Anova. For non-parametric distributions, Dunn's test was utilised to compare means post KW test. Cohen's d values used were 0.2 for a small effect size, 0.5 is a medium, 0.8 is considered a large with 1.2 being a very large effect size. Cohen's d was used to measure the size of the associations or differences between outcomes.

The statistical p-value boundaries have been set at 0.05 as in accordance with statistical methods. The statistical program R™ sets boundaries for graphical display at 0.1, 0.01, 0.001, 0.0001 to represent different levels of significance and this formatting has been carried through.

CHAPTER III: RESULTS

This chapter contains the anthropometric and physical results for the various tests conducted during experimentation. Where pertinent the findings have also been arranged according to age and maturity separately in two sections. Each stratification is ordered by anthropometric and physical results whereby significant findings are elucidated. For each of the variables a table is presented for both age and maturity groupings to give an overview of findings. Additionally, results are given as statistical significance with the range of values present along with a forest plot indicating the Cohen's d effect sizes between either age or maturity groups. This is done to ensure potentially small differences in performance which may not meet the threshold for statistical significance are reported accurately.

For each figure the stars denote p-value significance with no significance at 0.1, "*" for 0.05, "**" for 0.01, "***" for 0.001 and "****" for 0.0001.

3.1 Basic Demographic Information

Ethnicity and home language were unanimous in their response with 100% of respondents being isiXhosa speaking South Africans, identified in Table 10. 78% of individuals walked to school as their main commuting method, while only 11% where driven to school. The number of people in a households averaged 5.1 people with a standard deviation of ±2.29 people. A lack of medical aid is noted along with the corresponding monthly reported income of R3700 (± 4470). A wide variety of family members are responsible for providing household income with either both parents or the participants mother being the highest contributors.

Individuals started football training between the age of 9 and 10 with some variation present, ±1.98 years. Average experience was approximately 2.88 years with a substantial range of 2.04 years, which gives a coefficient of variation of 70.83%. Players reported an average training time of 8.7 hours a week for football specific training but with a standard deviation of ±4.09 hours. It should also be noted that no participants reported a training time above 10 hours a week. Little time was spent in unstructured or informal practice as seen by a 2.49 hours per week value.

The results obtained from the demographic questionnaire provided a general overview from participants of all ages and maturity status. Such information reflected the socio-economic and demographic environment present and would be expected to be similar between the various groups. For the different dependent variables, a large spectrum of results occurred due purposeful analysis of a cross section of age and maturity groups.

Table 10: General demographic, schooling, household, and footballing experience information of participants (n=112).

GENERAL DEMOGRAPHIC	**AGE (Years)**	12.61 ± 2.03
	ETHNICITY	African (100%)
	HOME LANGUAGE	IsiXhosa (100%)
SCHOOLING	**GRADE**	6.21 ± 2.18
	MODE OF TRAVEL TO SCHOOL	CAR (11%) WALKING(78%) TAXI (1%) BUS (8%)
HOUSEHOLD INCOME	**AVERAGE HOUSEHOLD MEMBERS**	5.1 ± 2.29
	FINANCAL PROVIDER	PARENTS (22%) MOTHER (21%) GRANDMOTHER (12%) FATHER (9%) GRANDPARENTS (8%) GRANT (6%) OTHER (12%)
	AVERAGE MONTHLY INCOME (R)	3668.60 ± 4468.60
	MEDICAL AID	Yes (17%) No (68%) N/A (15%)
FOOTBALL EXPERIENCE	**AGE STARTED**	9.84 ± 1.98
	EXPERIENCE (Years)	2.88 ± 2.04
	HOURS A WEEK	8.70 ± 4.09
	UNSTRUCTURED (Hours a week)	2.49 ± 3.58

3.2 Stratification by Age

Participants were allocated to their respective chronological age groups as indicated from the consent and demographic information forms. The different age groups were Under 11, 13, 15 and 19 with players allocated accordingly.

3.2.1. Tests of Normality, Homogeneity of Variance and Statistical analysis

In a study of this nature it is important to test for normality and homogeneity of variance to ensure the sample of the population is normally distributed and appropriate parametric tests can be run. If normality and homogeneity of variance are not found then appropriate steps can be taken to ensure accurate analyses of results are conducted. Furthermore, when comparing multiple age groups misleading conclusions can be made if data is skewed for a certain age or maturity bracket.

Table 11: A) and B) explore the physical variables of interest in this study for the various age groups.

A)

	Normality	Homogeneity of Variance	Statistical Analysis
	Shapiro Wilks	Bartlett Test	Anova
Height	0.11	0.3161	2E-16

B)

	Normality	Homogeneity of Variance		Statistical Analysis
	Shapiro Wilks	Bartlett Test	Fligner-Killeen	Kruskal-Wallis
Weight	0.0018	0.5257	0.5437	2.2E-16
Body Mass Index	1.637E-07	0.004149	0.7646	3.874E-07
Total Fat	4.109E-12	0.0002556	0.5969	0.1208
Power	7.784E-08	2.2E-16	2.896E-07	1.179E-11
Agility	0.004784	0.06563	0.0756	1.238E-09
Acceleration	0.0001991	0.9651	0.9279	8.561E-11
Speed	1.265E-05	0.3022	0.03478	2.789E-11
Endurance	7.091E-09	1.685E-06	0.3073	5.381E-09

Tests for homogeneity of variance and normality were only non-significant for height with graphical evidence seen in Appendix C.1. Other dependent variables were all found to have significant differences in either their homogeneity of variance or normality (see Table 11B). Height was found to have statistical significance between all age groups overall, while non-parametric dependent variables, apart from Total Fat Percentage, were also found to have significance between all age groups. Therefore, increases in total fat percentage did not differ greatly enough between age groups to warrant values being substantially larger or smaller. Therefore to deal with this the appropriate statistical methods were applied to the data.

3.2.2. Stature

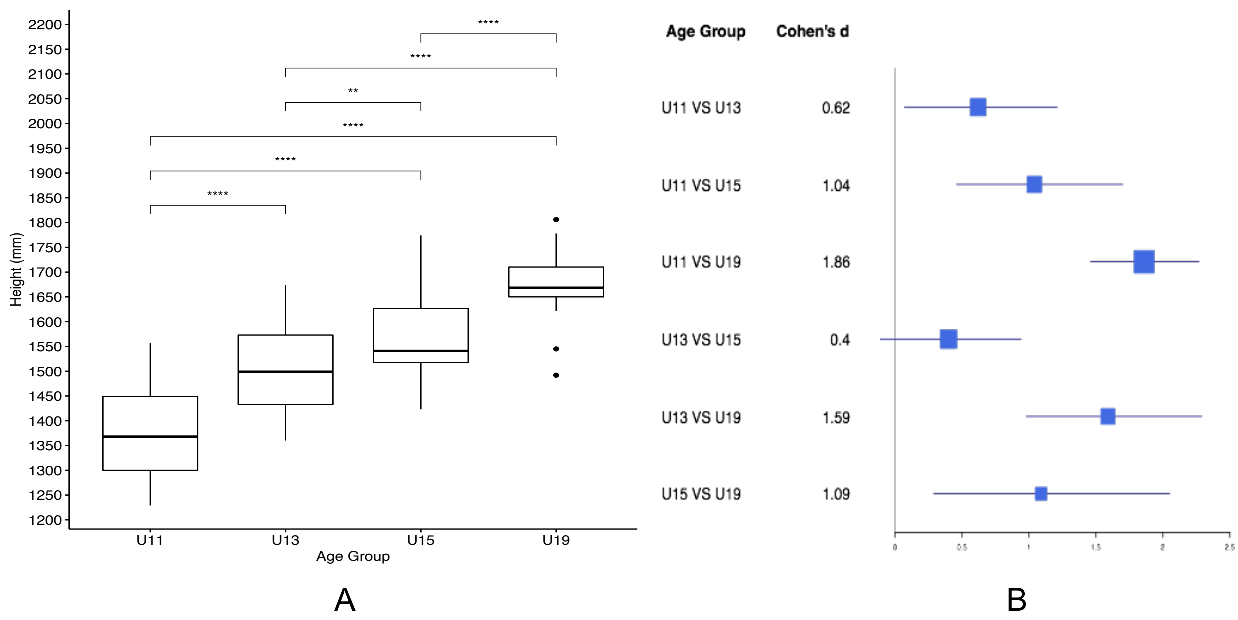


Figure 6: (A) Variation in stature (mm) between the different age groups. (B) Forest plot to show the effect size (Cohen's d) variation in stature between the age groups.

Significant differences for height were found between all the age groups (p-value: <0.001). Each age group was significantly taller than the preceding group with Under 11's having the shortest stature, 1377mm, and Under 19's being the tallest at 1678mm.

The effect size of 1.86 shown in figure 6B between U11 and U19 age groups corresponds to a very large effect size. The effect size was also relatively large for most of the other group comparisons except for the Under 11 to Under 13 group, as well as the Under 13's and Under 15's.

3.2.3. Weight

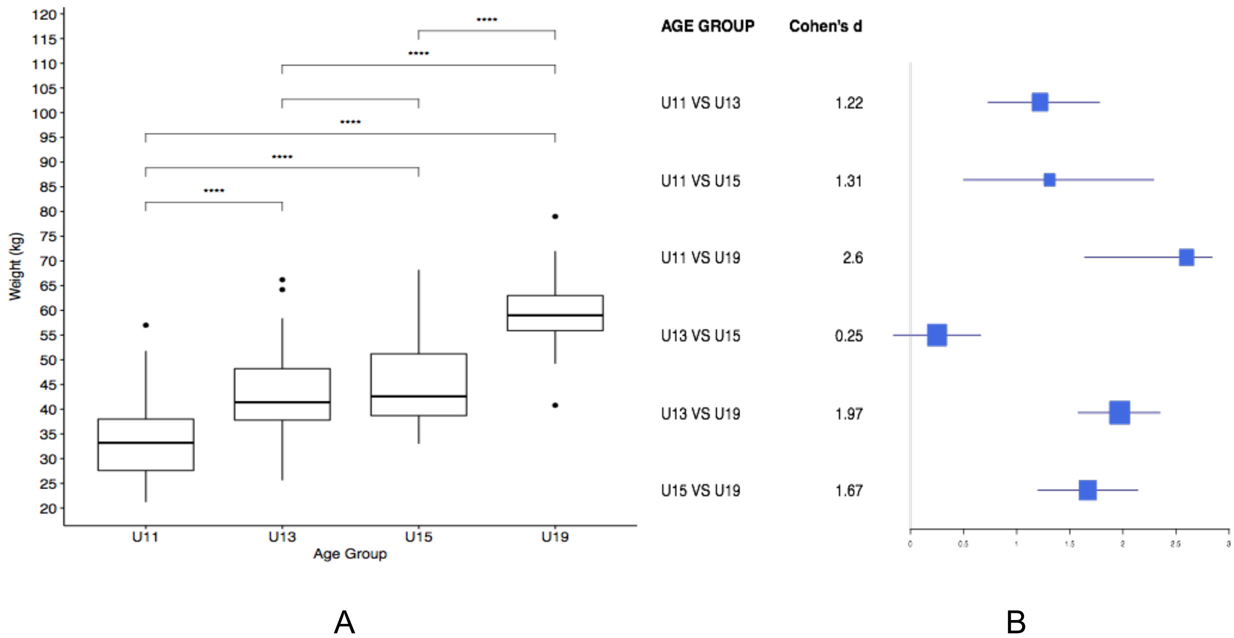
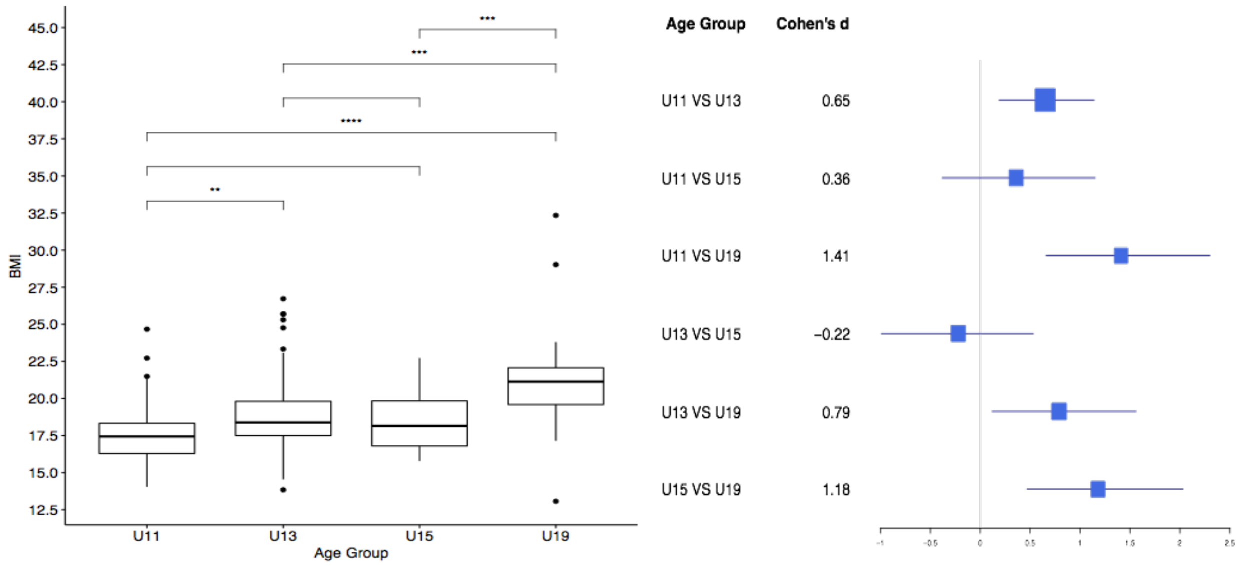


Figure 7: Variation in weight (A) and effect size (B) according to the different age groupings.

As indicated by Table 11, non-parametric analysis showed a significant overall effect, p-value: <0.001. However, the Under 13 (43.15 ±8.5kg) and Under 15 (45.34 ±9.27kg) groups were deemed to be similar, p-value: 0.5. There was a significant difference between all other age groups with an increase in weight from the Under 13 and Under 15 groups to the Under 19 group, with the older players weighing 59.21 (±7.4kg). Additionally, a significant drop in weight was present for the Under 11 group, who weighed 33.9 (±7.45kg), to all other age groups.

Under 13’s had a small effect size (0.25) when compared to Under 15s with this substantiating the p-value of 0.5 indicating no significance. Very large effect sizes were found for all other age group comparisons.

3.2.4. Body Mass Index



A B

Figure 8: (A) Body Mass Index per each age group. (B) Effect size forest plot for comparisons between each age group.

A significant overall effect, p-value: <0.001, was present for Body Mass Index. Although the Under 11s reported the lowest value of 17.66 (±2.09kg/m^2) this figure was statistically similar to the Under 15 age group BMI of 18.39 (±1.97kg/m^2). However, a medium effect size is present between Under 11 and Under 15 (0.36). The Under 19’s were significantly different to all other age groups.

No significance was found between Under 13 and Under 15 players, with Under 13 having a BMI of 19.11 (±2.8kg/m^2). Under 13 to Under 15 groups had a small effect size of -0.22 indicating the drop in BMI for Under 15’s. Furthermore, a large effect size of 1.18 differentiated between the Under 15 and Under 19 age groups.

3.2.5. Total Fat

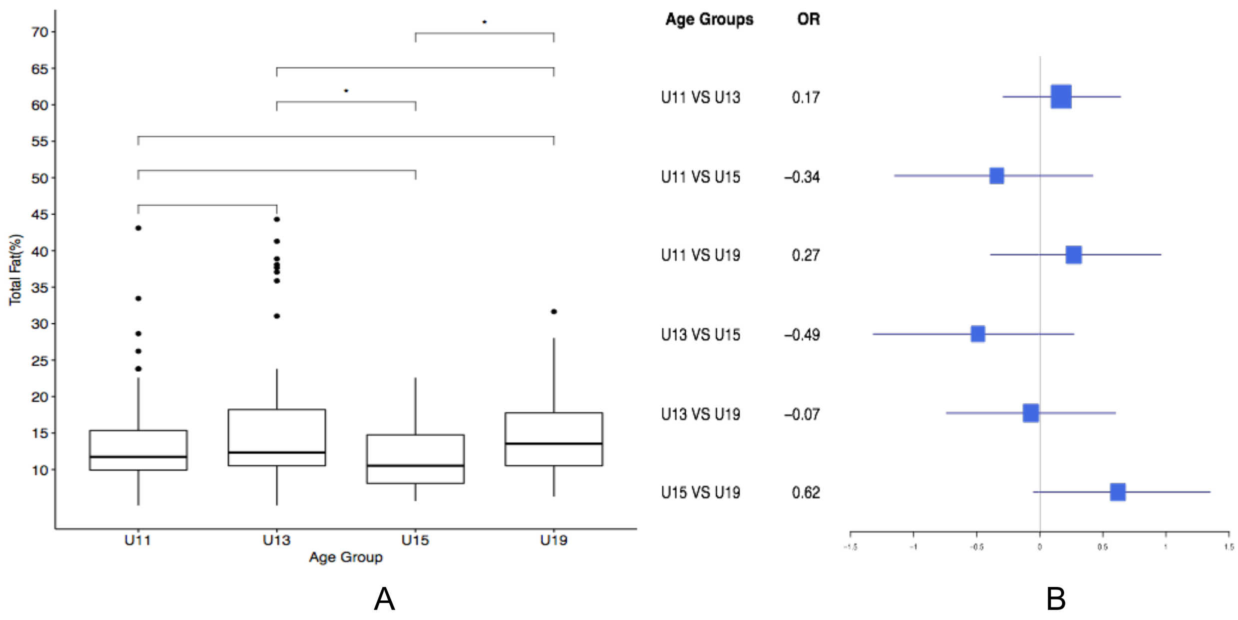
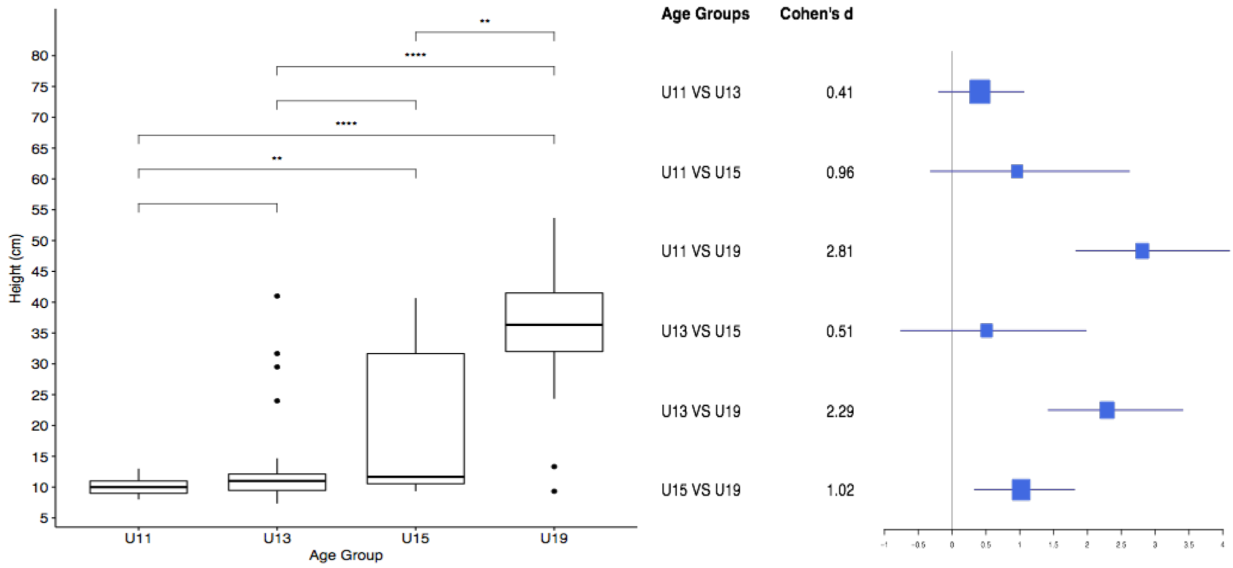


Figure 9: (A) Total fat percentage in the different age groups. (B) Comparison of effect sizes between the different age group total fat percentages.

Statistical analysis revealed no overall significance difference between age groups for total fat percentage (p-value=0.1208), indicating similar levels of total fat percentage across the various age groups. The average total fat percentage for the participants was 14.71 (±7.96%). This varied between Under 15 with the lowest percentage of 11.64 (±4.69%), and Under 13 who had the highest percentage with 16.46 (±10.04%). There was relatively large variation in each of the groups, typified in the Under 13 group who had a coefficient of variation of 63%. Large outliers are present, with certain values being classified as above 30% total body fat.

The Cohen's d for all age group comparisons was small to medium indicating the minimal differences present between results. The only exception being the Under 15 to Under 19 groups which had a large effect size of 0.62.

3.2.6. Power



A B

Figure 10: (A) Difference in vertical jump height (cm) according to age groups. (B) Effect size differences between various age groups.

Statistical analysis revealed a significant difference for vertical jump height. No significant differences between the Under 11's, Under 13s and Under 15s occurred with jump heights of 10.14 (±1.24cm) for Under 11, and 19.55 (±13.25cm) for Under 15 being recorded. The Under 19's, 35.41 (±9.27cm), had a significantly higher jump height when compared to younger age groups Under 11 (p-value: <0.001), Under 13 with (p-value: <0.001) and Under 15 (p-value: 0.017) as indicated by Figure 10A.

The large standard deviation and coefficient of variation (CV) in the Under 15 group, as evident by Figure 10A, of 67.78% should be noted. This compares to variance of 12.19% and 57.92%, for the Under 11 and Under 13 age groups, respectively.

Under 11 to Under 13 (0.41) had a small effect size for power output, with Under 13 to Under 15 classified as a medium interaction (0.51) as seen in Figure 10B. Under 11 to Under 19 was the largest difference with a Cohen's d of 2.81, considerably higher than initial boundaries in place for effect sizes. Under 13 to Under 19 was also a very large effect size with a Cohen's d of 2.29.

3.2.7. Agility

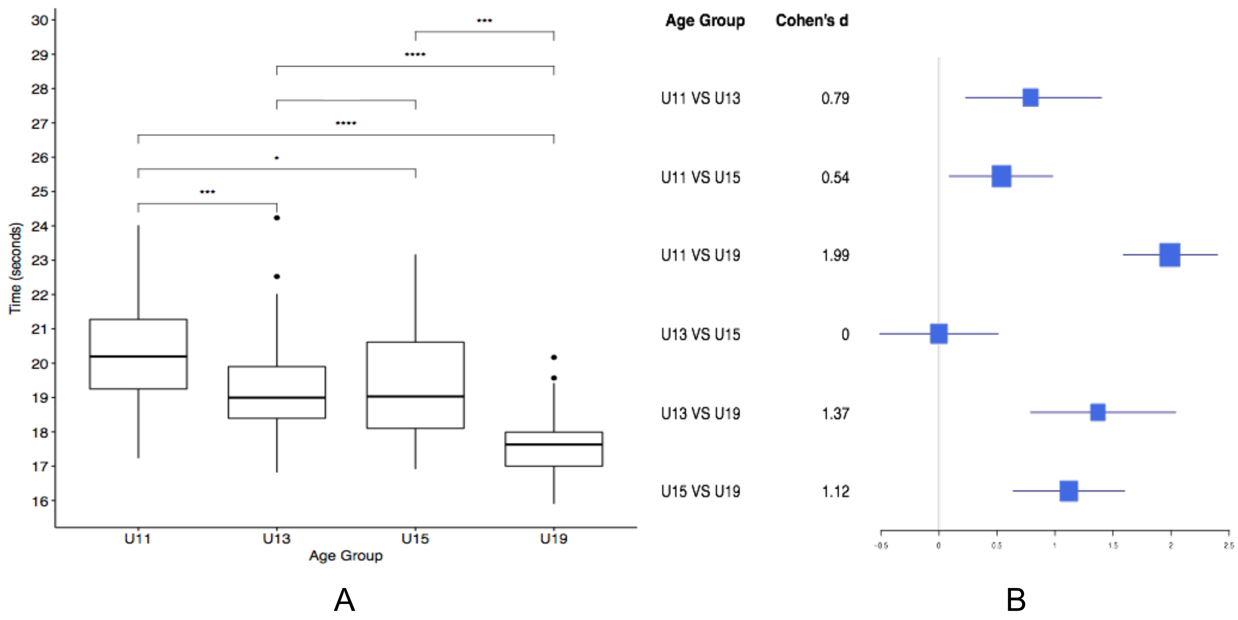
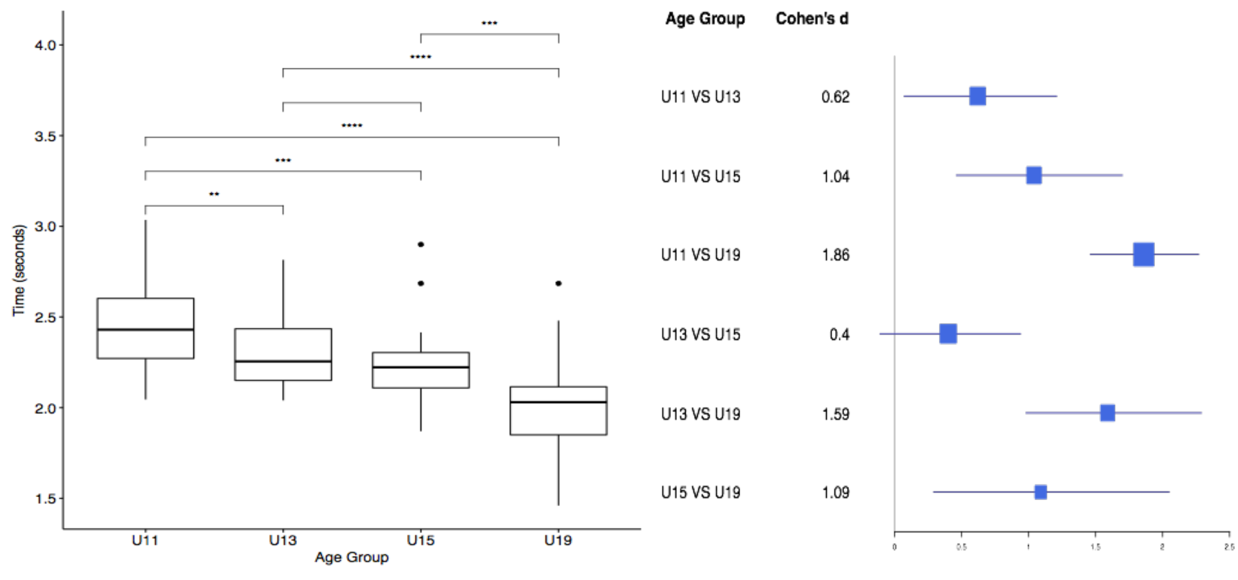


Figure 11: (A) Variation in agility time (seconds) between the different age groups. (B) Comparison of effect size differences for agility according to age group (seconds).

An overall significant effect was observed for agility time apart from between the Under 13's and Under 15's, p-value: <0.001. Under 11's averaged 20.34 (±1.5s) to complete the agility run and were the slowest of all age groups. Timings for Under 13's (19.3 ±1.41s) and Under 15's (19.45 ±1.91s) were not significantly different. The Under 19's were the fastest age group with a significantly faster time of 17.64 (±1.11s).

An effect size of 0 for Under 13 to Under 15 indicates no difference in time to complete the agility run. An upper and lower confidence interval of -0.5 and 0.5 shows a wide disparity in performance level. All other effect sizes were considered medium, such as Under 11 to Under 15 being 0.54, or large to very large.

3.2.8. Acceleration



A B

Figure 12: (A) Rate of acceleration time (seconds) between the different age groups. (B) Comparison of each age group with regard to effect size difference.

Figure 12A details how acceleration between age groups differed significantly, p-value: <0.001. The Under 11's being the slowest at 2.44 (±0.22s). Under 11's were significantly slower than Under 13's as represented by p-value: 0.021. Under 13 and Under 15 groups posted times of 2.32 (±0.21s) and 2.23 (±0.23s), which were statistically similar (p-value: 0.1395). The Under 19 players were quickest at 2.02 (±0.23s). Significant differences between Under 19 and all other age groups are reported.

The smallest interaction effect was between Under 13 and Under 15 with a Cohens d of 0.4, corresponding to a small effect size. Under 11 against Under 13 was a medium effect size with additional differences in acceleration between age groups classified as large or were above a Cohen's d value of 1.2.

3.2.9. Speed

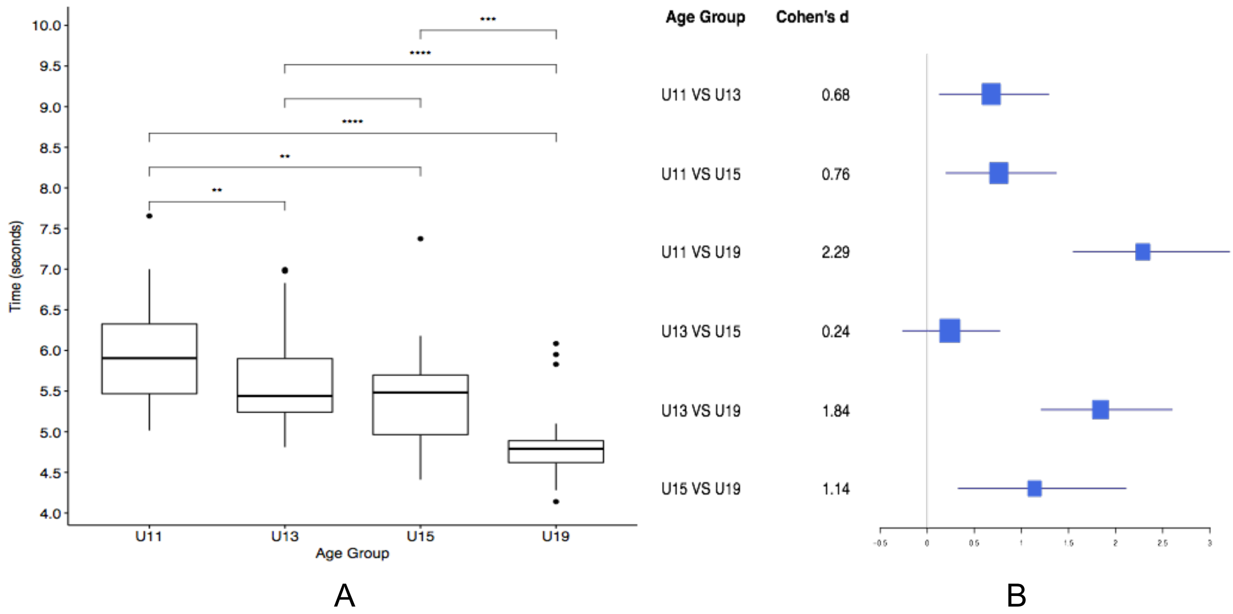


Figure 13: (A) Differences between age groups in terms of time (seconds) to complete 30m sprint. (B) Comparison of effect size differences in speed between different age groups.

Under 11s were significantly slower than all three older groups with a time of 5.93 ±0.57s(p-value of: 0.0181 for Under 13's, 0.0046 for Under 15's and <0.001 for Under 19's). The time difference was most notable between Under 11's and Under 19's, who registered an average time of 4.84 (±0.45s), 1.09s faster than the Under 11 players. The Under 13s and Under 15's were the only two groups not significantly different to each other at p-value: 0.36.

Under 11 to Under 19 recorded a very large effect size of 2.29, supporting the large p-value found. A small effect size between Under 13 to Under 15 represented the similar times observed during testing as shown in Figure 13B.

3.2.10. Endurance

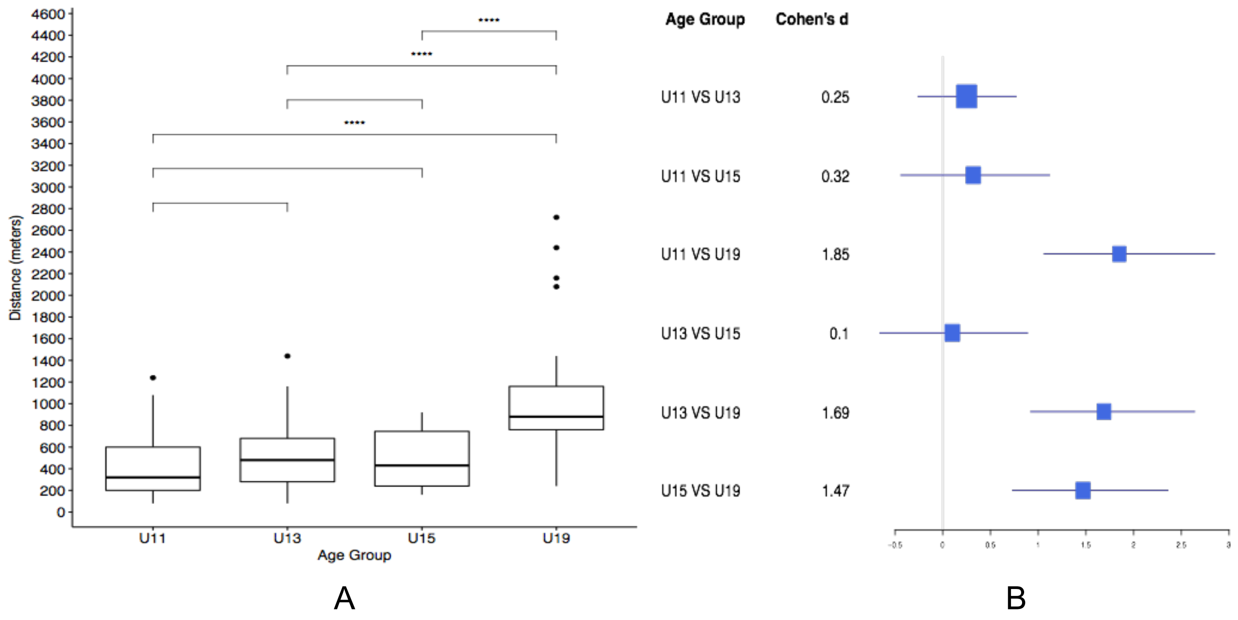


Figure 14: (A) Differences between age groups in terms of distance (meters) completed during Yo-Yo intermittent test. (B) Effect size comparisons for distance covered according to age group

Although there were incremental increases in distance covered from U11 to U15, these values were statistically similar (Under 11's travelled 420.5 ± 274.51m, while Under 13's managed 475.56 ± 281.62m and Under 15's ran for 496.36 ± 282.82m). While the Under 19's completed the greatest distance during the YYIR with an average of 1084 (±584m) making it significantly further than the distance covered by the younger age groups.

Small effect sizes occurred between Under 11 to Under 13 and Under 15 age groups with values of 0.25 and 0.32. A trivial effect size was found for Under 13 to Under 15 with a Cohen's d of 0.1, although a large confidence interval was present. Very large effect sizes are present when contrasting Under 11 (1.85), Under 13 (1.69) and Under 15 (1.47) to the oldest participants.

3.3. Stratification by Maturity Status

As mentioned previously in section 2.2.1, individuals were stratified by both their current chronological age grouping and their maturity status according to PHV results and testing.

3.3.1.Tests of Normality, Homogeneity of Variance and Statistical analysis

Table 12: Overview of maturity status results that were parametric.

	Normality	Homogeneity of Variance	Statistical Analysis
	Shapiro Wilks	Bartlett Test	Anova
Height	0.328	0.3352	2E-16
Weight	0.07946	0.3314	2E-16
Acceleration	0.1777	0.5936	6.83E-08

Normality and homogeneity of variance were confirmed for Height, Weight and Acceleration with subsequent statistical testing indicating significance between the maturity groupings. Graphical evidence can be seen in Appendix C.1.

Table 13: Overview of maturity status results that were non-parametric

	Normality	Homogeneity of Variance		Statistical Analysis
	Shapiro Wilks	Bartlett Test	Fligner-Killeen	Kruskal-Wallis
Body Mass Index	9.402E-07	0.03986	0.8867	2.539E-07
Total Fat	4.112E-09	0.001691	0.854	0.0882
Vertical Jump	1.767E-05	2.2E-16	8.875E-07	1.178E-09
Agility	0.002445	0.1523	0.2343	9.004E-06
Speed	0.000124	0.002503	0.02247	3.371E-08
Endurance	0.0001641	2.787E-07	0.009091	5.446E-08

As evident in Table 13, all other dependent variables were non-parametric. Agility had non-significant homogeneity of variance but the data did not conform to normality testing. All non-parametric variables under went statistical analysis with total fat percentage being the only non-significant result.

3.3.2. Stature

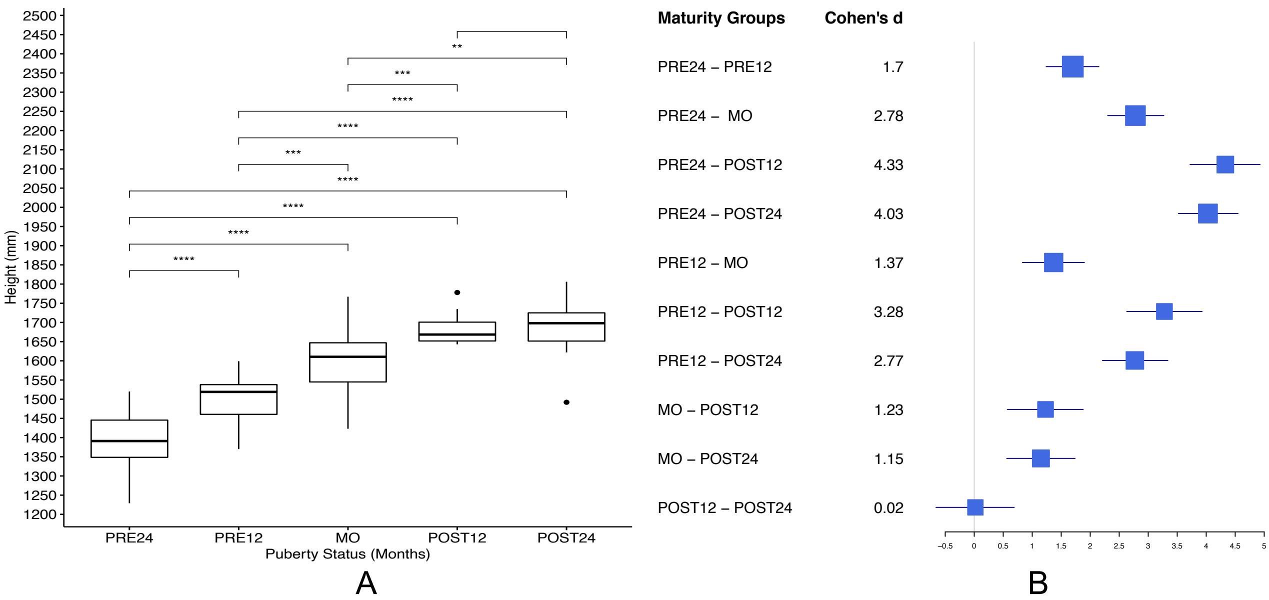
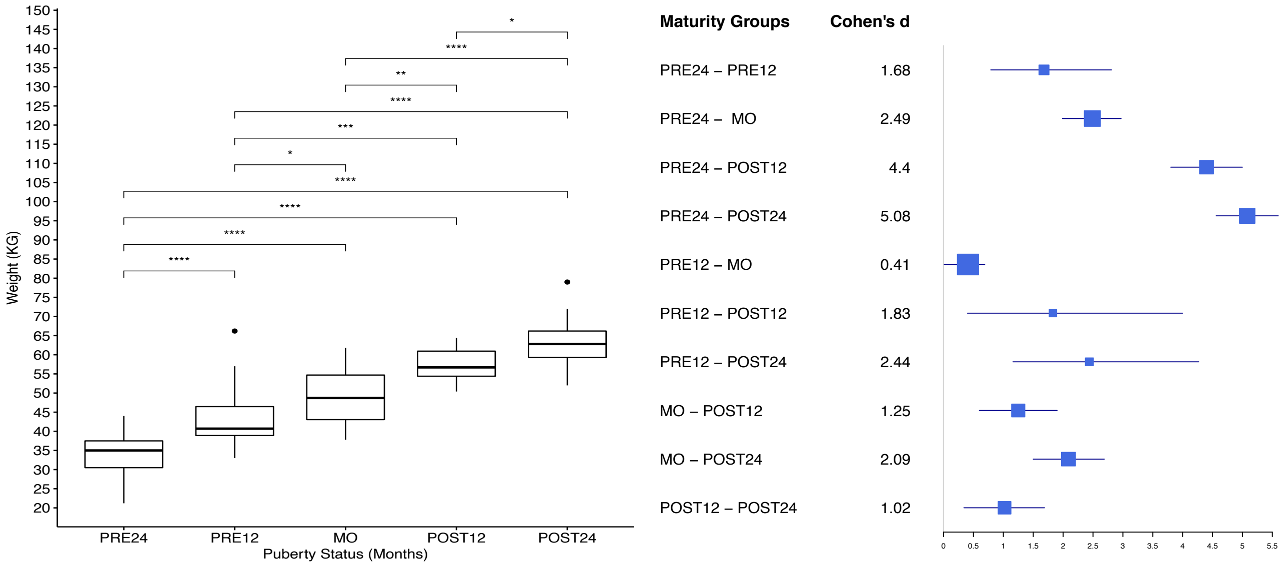


Figure 15: (A) Stature (milimeters) according to maturity status (B) Effect size comparison between the different maturity groups with regard to stature.

As according to Figure 15A, incremental increases in stature are noticeable for individuals PRE24, PRE12 and within a year of peak height velocity, with values of 1505.14 (±58.55mm), 1389.91 (±73.1mm) and 1598.11 (±78.06mm), respectively. All interactions had significant differences (p-value: <0.001), except between individuals who were 12 months (1684.4 ±44.12mm) past peak height velocity and 24 months (1685.67 ±73.83mm) past.

No difference was found in terms of effect sizes for those 12 months past peak height maturity and those 24 months past (Cohens d: 0.02). Very large effect sizes, above a Cohen's d score 1.2, were noted for all other maturity group interactions as depicted in Figure 15B.

3.3.3.Weight



A B

Figure 16: (A) Weight (kg) according to maturity status. (B) Weight comparisons between age groups with regards to Cohen's d effect size

There was no significant difference between the POST12 and POST24 maturity status groups. The values for each group were 57.2 (±4.58kg) for POST12 and 63.41 (±6.6kg) for POST24. There were however significant differences between all other groups.

A Cohen's d score of 0.41 indicates the PRE12 and MO had a medium effect size, evident in Figure 16B. Although POST12 and POST24 were considered a non-significant different a large effect size of 1.02 was calculated. All additional comparisons had a very large effect size difference, most notable PRE24 and POST24. Large 90% confidence intervals are also noted PRE12 and POST12 groups (Lower: 0.4, Upper: 4), and the PRE12 to POST 24 groups (Lower: 1.16, Upper: 4.27).

3.3.4. Body Mass Index

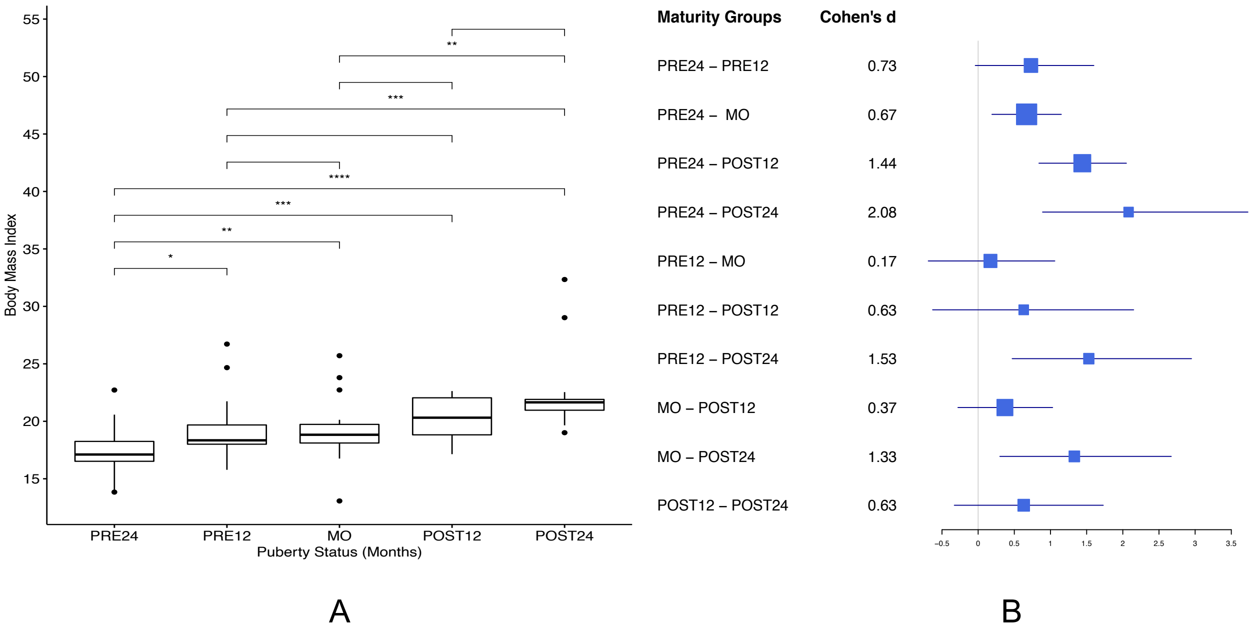


Figure 17: (A) Differences in body mass index according to maturity status. (B) Effect size difference comparisons between the various maturity groups for body mass index.

Individuals in the PRE24 group had the lowest BMI, with a value of 17.47 ±1.86kg/m^2. This is significantly lower than PRE12 (p-value: 0.0168), MO (p-value: 0.0115), POST12 (p-value: 0.0025 and POST24 (p-value: <0.0005). With values of 19.09 (±2.62kg/m^2), 19.22 (±2.8kg/m^2)and 20.2 (±2.01kg/m^2), no significant differences were found between the PRE12 group, those experiencing maturity offset, and the POST12 maturity group. Additionally, POST12 and POST24 groups did not have significantly different BMI values (p-value: 0.1798).

PRE12 and MO had a small effect size of 0.17 which was the lowest. The MO and POST12 groups had a medium effect size of 0.37. All other comparison were considered large or very large. Large 90% Confidence intervals are also present for comparisons apart from PRE24 to MO groups as well as the PRE24 to POST12 groups.

3.3.5. Total Fat

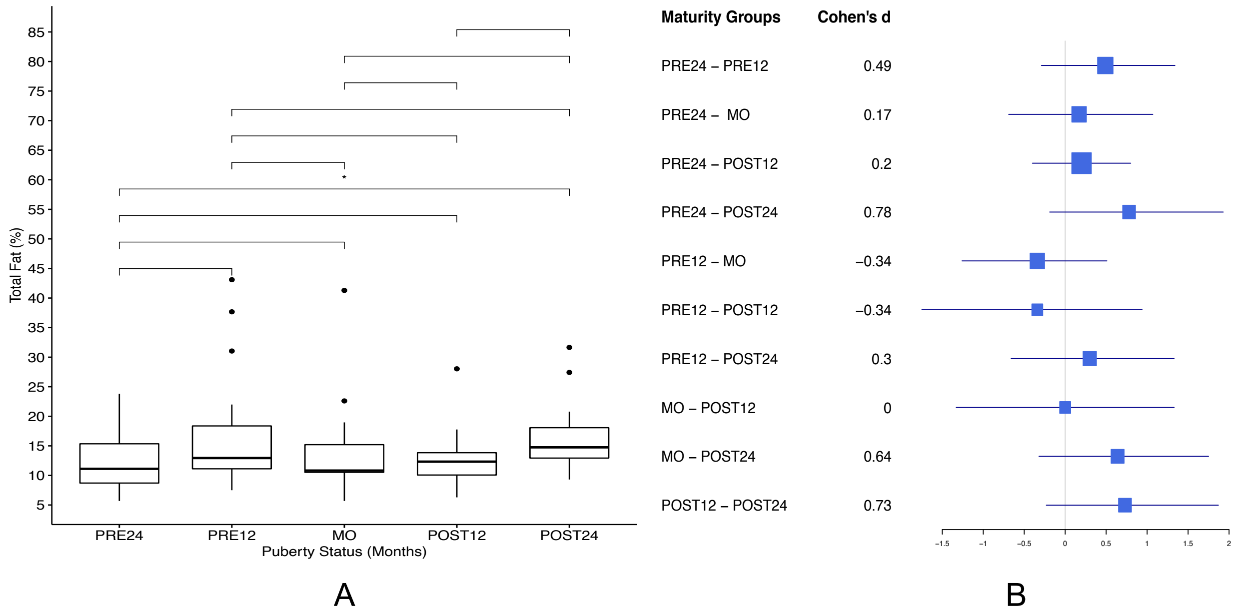


Figure 18: (A) Total fat percentage for individuals according to maturity status. (B) Total fat percentage in terms of Cohen's d score comparison between the relevant maturity groups.

No overall significant effect was found for all conditions, as shown in Table 12, above. The lowest fat percentage was the PRE24 group with 12.14 (±4.35%), the highest being 16.59 (±9.65%) for the PRE12 group. The maturity offset and POST12 group recorded similar fat percentage levels at 13.9 (±8.1%) and 13.1 (±6.22%) for each respectively.

Although no significance was found for fat percentage between maturity groups, medium to large practical effect sizes are present. A similar effect size is present whether a comparison is made between the PRE24 maturity group to the POST24 (0.78), or if the POST12 maturity group is evaluated against the POST24 group. No effect size is present for maturity offset to 12 month past but a very large 90% confidence interval is present.

3.3.6. Power

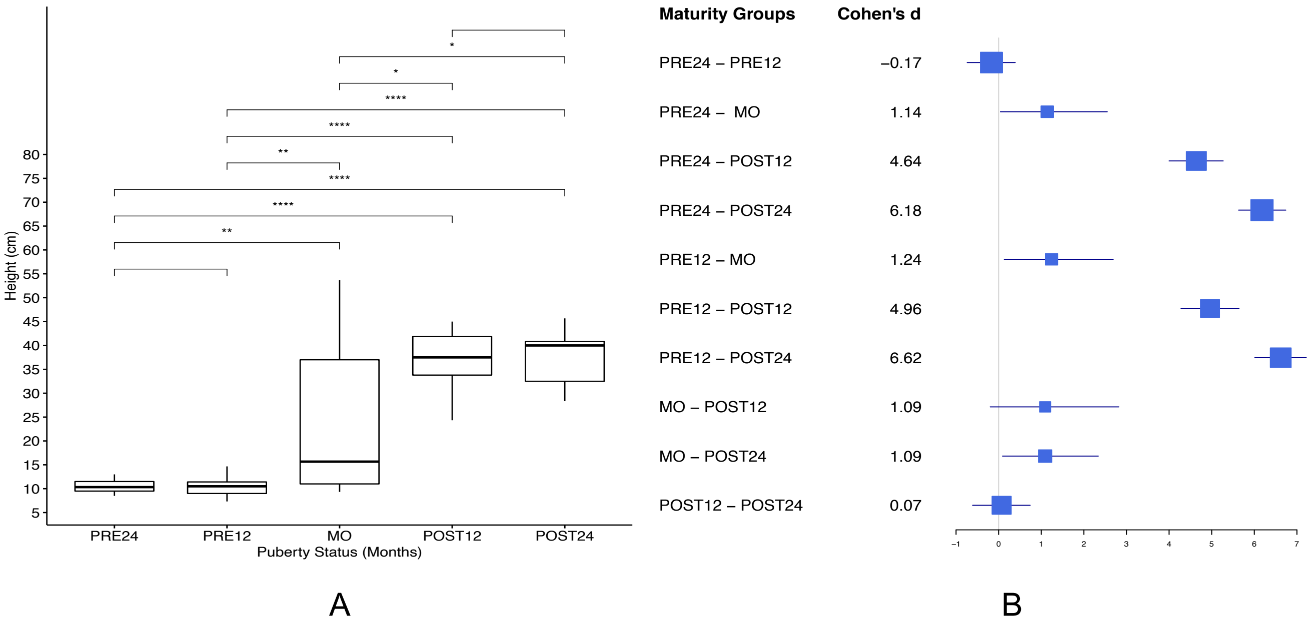


Figure 19: (A) Vertical jump heights (cm) displayed by maturity status. (B) Comparison of effect size differences between age groups for vertical jump height.

A non-significant differences was observed between the PRE24 and the PRE12 maturity groups with heights of 10.6 (±1.49cm) and 10.3 (±1.92cm), respectively. The large range present for jump height for the MO, 23.9 (±15.15cm), created a large CV of 63.39%. A significant difference was however found between the MO group and all other maturity groups as shown in Figure 19A. Further, the results for POST12 and POST24 were also non-significant at p-value: 0.82.

Figure 19B highlights the lack of effect size observable between the PRE24 and PRE12 as well as between the POST12 and POST24 maturity groups. All other comparisons experienced a very large - above a Cohen's d value of 1.2 - effect size difference

3.3.7. Agility

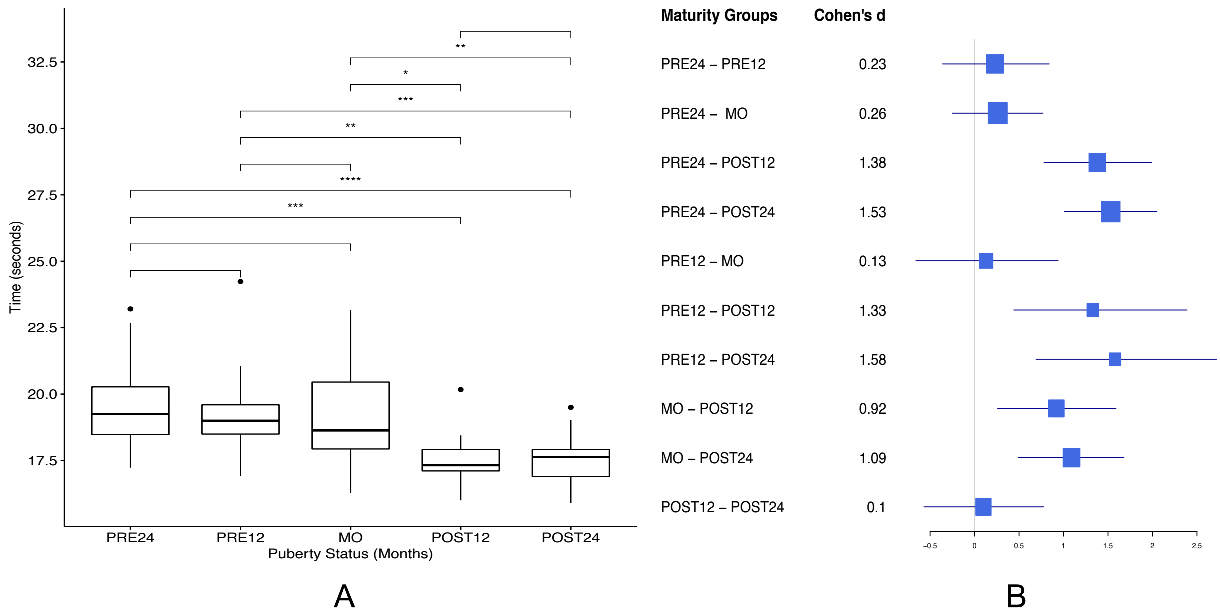


Figure 20: (A) Agility times (seconds) after completion of the Illinois agility test according to maturity status. (B) Effect size differences for agility between maturity groups

Figure 20A depicts similar responses for PRE24, PRE12 and MO groups with no significant differences between the times of: 19.57 (±1.52s), 19.28 (±1.55s) and 19.15 (±1.88s) respectively. A notable decrease in time is evident for POST12 (17.58 ±1.14s) and POST24 (17.47 ±0.98s) from less mature groups. A significant decrease in time, with a p-value difference of 0.033 and 0.01, was evident for the POST12 and POST24 groups against the maturity offset group.

The PRE12 to MO group, and the POST12 to POST24, had no noticeable effect size difference in alignment with no p-value significance. The PRE24 against PRE12 (0.23), and PRE24 compared to MO (0.26) had a medium effect size represented in Figure 20B . PRE12 and POST12 (Lower: 0.48, Upper: 2.39) along with the PRE12 and POST24 (Lower: 0.69, Upper: 2.72) had large confidence intervals which ranged from medium to very large interaction effects.

3.3.8. Acceleration

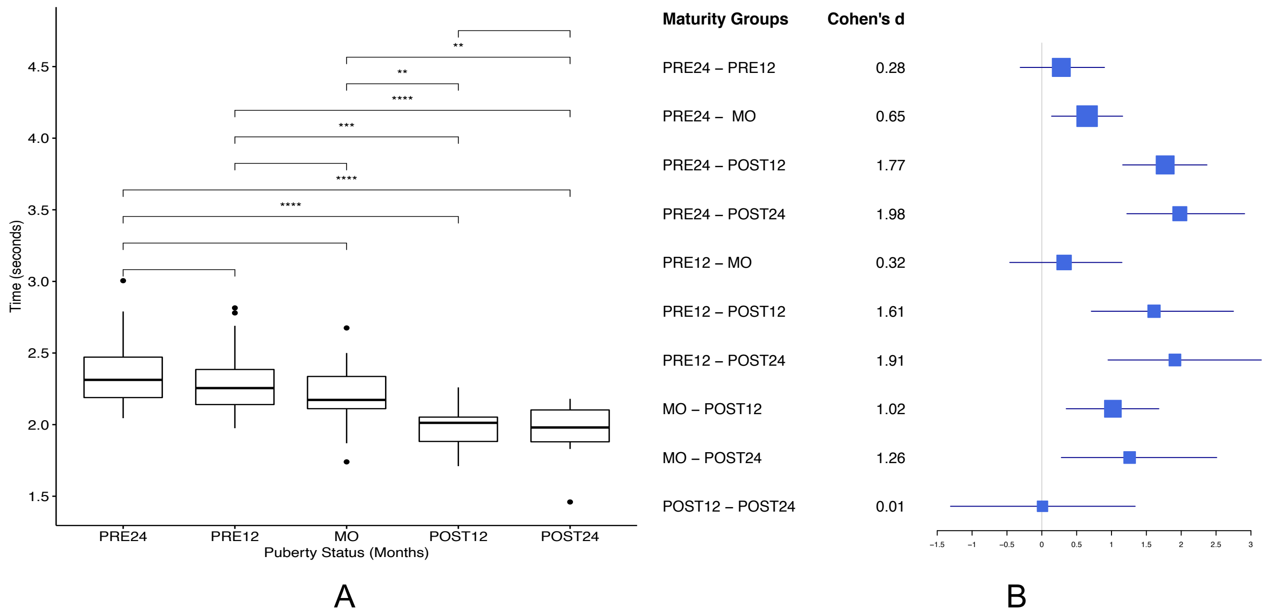


Figure 21: Variation in acceleration (A) and effect size (B) according to the different maturity groupings

With times of 2.36 ±0.22s, 2.30 ±0.23s and 2.21 ±0.24s no significant differences were found between PRE24, PRE12 and MO groups for acceleration. Similarly, no statistical difference was found between POST12 (1.99 ±0.15s) and POST24 (1.97 ±0.18s) maturity groups. However, there was a significant drop - p-value: 0.01 and 0.006 - between MO group and the POST12 and POST24 group.

For figure 21B, a medium practical effect size was noted for PRE24 to PRE12, PRE24 to MO and PRE12 to MO. A large effect size for MO to POST12 (1.02) and a very large effect size for MO to POST24 (1.26) were observed. No effect size difference (0.01) was calculated between POST12 and POST24.

3.3.9. Speed

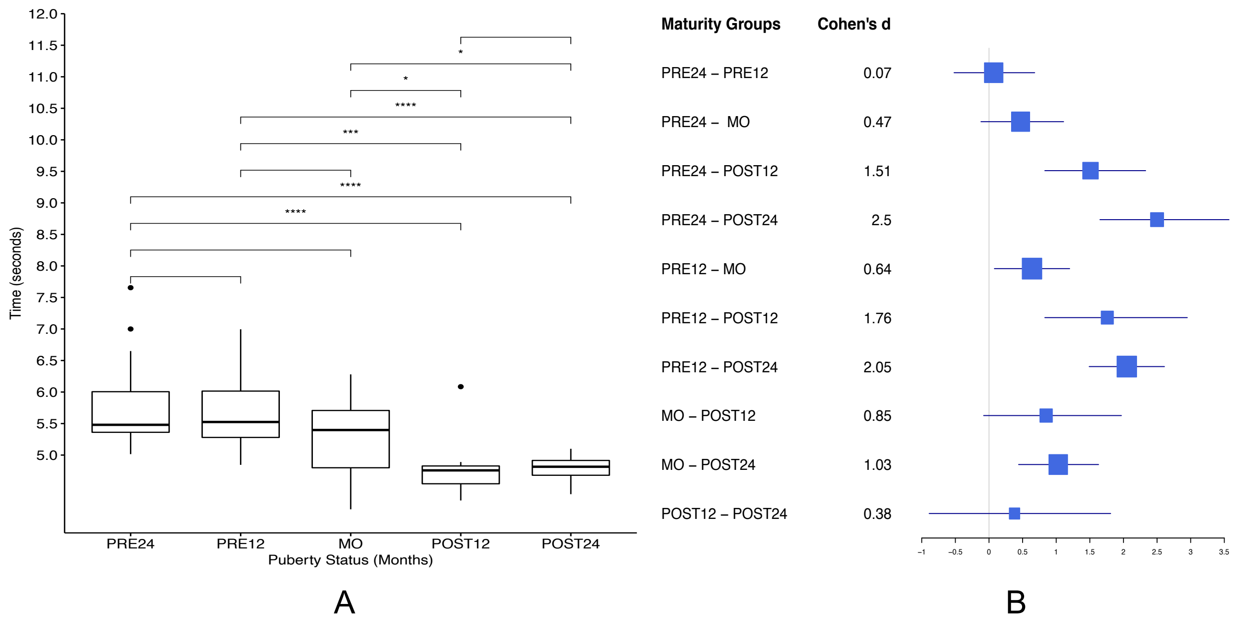


Figure 22: 30 meter speed times (seconds) according to (A) maturity status and (B) effect size difference between groups.

The pattern of results for speed matched that of acceleration whereby PRE24, PRE12 and MO were all statistically similar. Times of 5.69 ±0.58s, 5.65 ±0.59s and 5.27 ±0.61s, respectively, were recorded and presented in Figure 22A. The maturity offset group was statistically slower than the participants in the POST12 group (p-value:0.047) and the POST24 group (p-value: 0.025). Furthermore, no significant differences where found between POST12 (4.79 ±0.5s) and POST24 (4.78 ±0.2s).

Individuals in the PRE24 and PRE12 group had no practical difference in their speed times as indicated by an effect size of 0.07. Medium effect sizes for PRE24, PRE12 and the MO group highlighting significant increases in speed. POST12 and POST 24 groups had a medium effect size of 0.38. Maturity groups separated by more than a single group experienced very large effect size differences, such as PRE24 to POST 12 (1.51), PRE12 to POST12 (1.76) or MO to POST24 (1.03)

3.3.10. Endurance

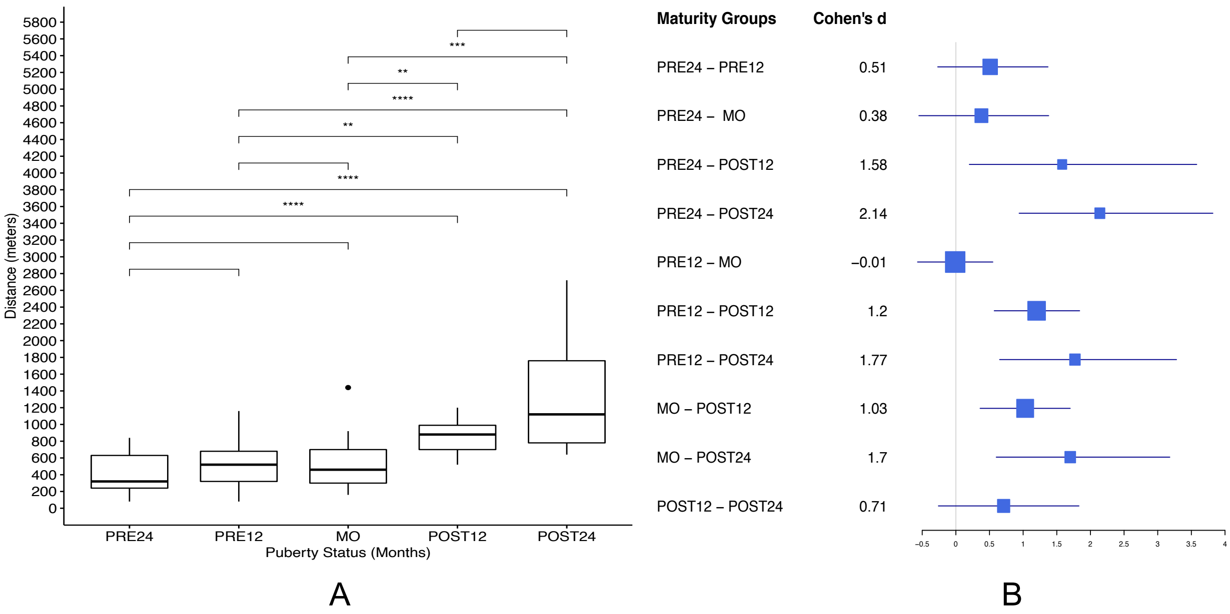


Figure 23: Distance covered (meters) during the Yo-Yo Intermittent Recovery Test according to (A) maturity status and (B) effect size difference between groups.

The PRE24, PRE12 and MO experienced high CV levels with values of 55.58%, 51.24%, and 64.12%. Recorded distances were 399.41 ±221.97m, 541.9 ±277.7m and 540 ±346.26m, respectively, although these values were deemed to be statistically similar. The POST12 group covered a significantly greater distance than the PRE24 (p-value: <0.001), PRE12 (p-value: <0.001) and MO (p-value: 0.00757) groups with a total distance covered of 860 ±202.43m. A large standard deviation was found for the POST24 months group, 1338.67 ±688m, resulting in a CV of 51.4%. As evident by Figure 23A, there was a large quartile range with the 1st quartile at 780m and the 3rd quartile at 1760m. The POST24 group ran a significantly greater distance than all other maturity groups apart from the POST12 participants.

Distance covered between PRE12 and MO populations had no effect size difference, at -0.01. Additionally a medium effect of 0.51 was found for PRE24-PRE12 along with PRE24 to MO (0.38). A large effect size was present between POST12 and POST24 at a Cohen's d of 0.71 resulting from the increased distance covered. A very large effect size was noted when comparing PRE24, PRE12 and MO to POST24 individuals.

Table 14. Overview of statistical findings with significance and non-significance indicated for each tested component.

	Stature	Weight	Body Mass Index	Total Fat %	Power	Agility	Acceleration	Speed	Aerobic Capacity
Age	0.0001	0.0001	0.0001	0.1208	0.0001	0.0001	0.0001	0.0001	0.0001
Maturity	0.0001	0.0001	0.0001	0.0882	0.0001	0.0001	0.0001	0.0001	0.0001

Total fat percentage was found to not be statistically significant for either age or maturity status. All other components differed significantly indicating a disparity in either anthropometric characteristics or physical ability between age groups and of differing maturity status.

CHAPTER IV: DISCUSSION

4.1 Overview

The discussion will comprise of four separate parts: detailing a comparison against playing populations of similar age and maturity, the implications of these results for the studied population, potential reasons of results and possible solutions moving forward to improve performance of the cohort present in the current study.

4.2 Age and Maturity Stratification

4.2.1 Anthropometric stratification by age & maturity

4.2.1.1 Height

Increases in stature with age are to be expected in young individuals with growth slowly subsiding at age 16 and full height reached by the age of 18 (Viru *et* al., 1999; Naughton *et al.,* 2000; Rogol, Roemmich & Clark, 2002). For certain positions stature is an important variable when selecting players, and style of play is influenced by the general anthropometric characteristics of participating individuals.

For the current study, stature increased with each age group, albeit with no significant difference in stature between the Under 13 and Under 15 players. Furthermore, the Under 19s had the smallest range and coefficient of variation for stature indicating individuals were close to their maximal stature with growth rates having subsided for each player.

Maturity positively affected stature increases up until individuals were 12 months past their maturity when heights plateaued. The negligible effect size difference between individuals in the POST12 and POST24 groups for stature indicates the possible attainment of maximal height (Rogol, Roemmich & Clark, 2002; Ford *et al.,* 2011; Lloyd *et al*., 2015). Therefore, age and maturity had a signifiant and practical effect on height for youth South African footballers.

Increased stature is an indication of the pubertal process occurring and results in different heights for the different age groups. Increased height can improve performance for various physical and physiological components, as detailed in section 1.2.7, and allows athletes to possess an advantage on the field of play. The attainment of maximal height in the oldest maturity groups represents the plateauing of the puberty process to which any advantages early maturers have are negated. The dispersion of data for stature results remains constant throughout the maturity groups, with CV's remaining between 3 and 5% although the largest CV values can be found for PRE24 (5.26%) and MO (5.19%) groups. It is difficult to ascertain the how much of an advantage individuals who experience early maturity experience have, due to the one off testing nature of the study. Longitudinal analysis with regular assessments of players anthropometric characteristics within the same age group would be needed.

Height values in comparison to certain nationalities and ethnicities with playing level also being an important variable. As evident in Table 2, a large variation is present in the statures of youth footballers when first comparing by age and then by maturity status. The average stature of the Under 19 group was 1678mm and this would be shorter than Under 16 populations from France (Le Gall *et al.,* 2008), Qatar (Buchheit, 2013), Brazil (Cunha *et al*., 2013) and Japan (Hirose *et al*., 2015) which indicates a reduced stature profile. This is also evident at younger age groups as Under 13 players from Germany (Honer *et al*., 2014), Finland (Forsman *et al*., 2015) and England (Portas *et al*., 2015) were all taller or of similar stature than Under 15 players from this study. These findings are consistent with studies of general populations, which show that South African children have an average height of between 1400-1550mm for boys aged between 10 to 15 (McVeigh, Norris & de Wet, 2004; Monyeki *et al*., 2006; Kruger & Pienaar, 2009; Pienaar & Viljeon, 2010; Jacobs & De Ridder, 2012; Toriola, Monyeki & Toriola, 2015; Armstrong, Lambert & Lambert, 2016).

Stature of the current players when stratified by maturity, compared similarly against Elite Qatarian players most notably in the maturity offset group (Buchheit, 2013). Statures of 1529(±54mm), 1635(±82mm) and 1710(65mm) for elite French players are equivalent to the values found in the present study (Carling *et al.,* 2012).

However, Brazilian elite players had a greater stature at prepubertal, pubertal and post-pubertal maturity points (Cunha et al., 2013). Therefore it is evident that when stratified by maturity the heights of local South African footballers are similar to that of overseas populations.

4.2.1.2 Weight

It is imperative that a players weight is kept to an optimum in order to complete the required distance during a football match in an efficient manner (Reilly *et al*., 2000). Further, certain weight increases at specific points in a youth athletes development is an indication of the maturation process.

The effects of age on weight was an increase from Under 11 players until the age of 13 with the rate of weight gain subsiding at 15 years of age. Following the age of 15, a 14kg increase in weight occurred for the Under 19's. This signifies the onset of peak weight velocity and the increase in hormonal development with many benefits for athletic prowess (Ford *et al*., 2011). Large effect sizes are present between all age groups apart from the Under 13 and 15 participants. The present effect size differences are indicative of an actual change in weight between the age groups. Thus, the overlap in results between the Under 15 and Under 19 players is minimal. This is a significant finding showcasing the changes a youth player may experience during the ageing process and how a long term approach must be taken to developing youth players. A player at 14 may gain upwards of 14kg in weight before they compete at a senior level. Improvements in strength, power, acceleration and speed may be forthcoming from such developments (Ford *et al*., 2011).

Studies on South African players show players as being considerably lighter than populations of differing nationalities, such as Portuguese players (Malina *et* al., 2000; Figueiredo *et al*., 2009) and English players (Lovell *et al*., 2015; Portas *et al*., 2015) or ethnicity where Qatarian (Mendez-Villanueva *et al*., 2012), Japanese (Hirose *et al*., 2015) and Brazilian (Cunha *et al*., 2016) players of all ages were heavier. Elite level players from Belgium (Vaeyens *et al.,* 2006), France (Le Gall *et al*., 2008) and Italy (Castagna *et al*., 2003) were all noticeably heavier than the study population. What would be important to determine is if this additional weight is muscle or fat related. This can be further quantified when looking at total body fat percentages in the below section, 4.2.1.4.

Participants exhibited an unusual age related weight increase pattern due to the similarity in weight between the Under 13 and Under 15 players which is not noticeable in other footballing populations (Vaeyens *et al.,* 2006; Le Gall *et* al., 2008; Lovell *et al*., 2015; Portas *et al*., 2015). Weight gain when stratified by maturity was much more incremental with values falling in line with differences found in other studies (Carling *et al.,* 2012; Buchheit *et al*., 2013). Therefore, maturity illustrates a more predictable pattern of growth with large effect sizes between ages exemplifying the increased weight gained by more mature players. Under 13 and Under 15 may have similar weights due to a delayed maturity onset with players only starting to experience puberty at a later age resulting in a later peak weight velocity.

Thus, maturity positively affected weight gain in youth South African footballers, albeit at a lower weight value than overseas populations, but at a similar rate and pattern.

4.2.1.3 BMI

Body Mass Index was significantly affected by both age and maturity. The values presented by the study population are comparable to players from Brazil (Candhas *et al*., 2010), Spain (Gil *et al*., 2014), Qatar (Mendez-Villanuev *et al*., 2010), Denmark (Stroyer *et al*., 2004), Belgium (Vadendriessche *et al.*, 2012) and Hong Kong (Wong *et al*., 2009).

A drop in BMI for Under 13 to Under 15 players was noticeable and this may be impacted by the similarity in weight between the age groups. The small weight increase between Under 13 and 15 players, in conjunction with a significant stature increase and changing body characteristics may have caused the BMI difference. The changing body characteristics may be the result of drop in fat percentage and an increase in muscle mass typified by adolescent growth (Rogol, Roemmich & Clark, 2002). Under 19 players had a higher BMI than younger players and the substantial gain in body mass is responsible.

Maturity groupings exhibits the same pattern of growth when compared to different study populations, with more mature individuals exhibiting a larger body mass index than less mature individuals (Stroyer *et al*., 2004; Mendez-Villanuev *et al*., 2010). Therefore, BMI was influenced by the increase in weight and subsequent slowing down of height velocity resulting in an increased BMI rating. In conjunction a decrease in fat percentage, depicted in Figure 17B, for the maturity offset and POST12 groups, with an increase in weight (seen in Figure 16B) represents an increase in lean muscle mass (Viru *et al*., 1999; Rogol, Roemmich & Clark, 2002). An important considering discussed in section 4.2.2. is the increase in performance possibly related to fat loss experienced by these groups. The subsequent increase in fat percentage, Figure 17B, for the POST24 group further increases the BMI rating.

4.2.1.4 Total Fat percentage

Low total fat percentage is important to possess due to the high physical demands placed on youth athletes, especially footballers. Additionally, fat percentage will drop as a youth athlete experiences the maturational process (Rogol, Roemmich & Clark, 2002).

Total fat percentages for each age group were all between 10% and 15%. In conjunction, total fat percentage was the only dependent variable to not be influenced by maturity. Maturity did not significantly affect total fat percentage although practical effect sizes were observable between certain age and maturity groups. The loss of fat just after peak height velocity is supported by literature as a natural phase of development (Rogol, Roemmich & Clark, 2002). The lack of effect size between MO and POST12 signifies this drop in fat, followed by a large effect size difference to more mature individuals who have finished the pubertal process. An increase in fat mass is expected as height velocity declines, which is present in Figure 15A (Rogol, Roemmich & Clark, 2002).

In comparison to various footballing populations of different ethnicities and nationalities, the current study had higher fat percentage levels overall for all age groups (Le Gall *et al*., 2008; Vadendriessche *et al.*, 2012). This is particularly visible when compared against elite Qatarian (Mendez-Villanuev *et al*., 2010) and French (Carling *et al*., 2012) footballing populations, regardless of age or maturity. When compared to non-elite Finnish players the current South African players had similar levels of total fat percentage, especially older participants (Vanttinen *et al*., 2011).

Non-significant differences in total fat percentage between age group and maturity groups are noted for different populations which corresponds to the pattern found in the current study (Vaeyens *et al.*, 2006; Le Gall *et al.*, 2008; Figueiredo *et al.*, 2009; Candhas *et al.*, 2010; Coelho e Silva *et al.*, 2010; Mendez-Villanuev *et al.*, 2010; Vänttinen *et al.*, 2010; Mendez-Villanuev *et al.*, 2011; Carling *et al.*, 2012; Gil *et al.*, 2014; Huijgen *et al.*, 2014).

4.2.2 Physical capacity results by age & maturity

4.2.2.1 Power

Power and strength are important components of physical development for performance in activities such as football. Without appropriate increases in muscle mass and strength, the ability to exert high levels of power is reduced (Bailey *et al.,* 2010; Turner *et al*., 2011).

Power showed a significant improvement during and after the age of 15 with effect sizes indicating improved performance for older participants. The large standard deviation and CV for the Under 13 and 15s is noticeable with a substantial jump in performance for individuals after this age, as evident in Figure 10A. Similarly, a large performance range was present for the maturity offset group during power testing, Figure 19A. A lack of statistical significance nor a practical effect size was present for the two groups before their maturity (PRE24 and PRE 12) and for the two groups who were past their maturity offset (POST12 and POST24). Therefore the effects of age and maturity had a similar outcome on power development.

The large CV and standard deviations, especially around the Under 13 and Under 15 groups are the result of individuals experiencing the pubertal process at different times. The variability in the age of onset and the tempo of puberty between individuals can be vastly different (Viru *et al*., 1999; Rogol, Roemmich & Clark, 2002). At the point of testing different Under 13 or 15 individuals may be 1 year into puberty to which this would bring about a series of changes, while others may only be a few months into their pubertal development. This will present as early maturing individuals being considered as better athletes or more talented due to their physical advantage at such a young age.

In reference to section 4.2.1, changes in anthropometric characteristics according to age and maturity, such as decreases in total fat percentage with an increase in stature and weight, coincide with the improvements in performance. Such an improvement during the pubertal process, and the difference in the puberty rate, evidently has an affect on the power ability of the present participants which may manifest itself during matches.

The Under 19 group and the POST24 maturity group produced a jump height of 35.41 (± 9.27) and 37.48 (± 5.2)cm, respectively. These values are typically lower than many elite and non-elite overseas study populations (Le Gall *et al.*, 2008; Buchheit *et al.*, 2010). Furthermore, Under 14 Spanish (Bidaurrazaga et al., 2014), Under 15 Qatarian (Buchheit *et al.*, 2010) and Under 16 French, Qatarian and Finnish (Le Gall *et al.*, 2008; Buchheit *et al.*, 2010; Vanttinen *et al*., 2011) populations achieved a better or similar vertical jump height.

Low jump heights are observable for all age and maturity groups when compared to populations of different ethnicity, such as Swiss players (Zubar *et al.,* 2016), nationality (Le Gall *et al.*, 2008) and playing level (Buchheit *et al.*, 2010; Bidaurrazaga *et al*., 2014) indicating a poor power ability of youth South African footballers from the current study. However, care must be taken when interpreting the results as lower power scores may be attributed to a lack of familiarisation with the testing procedure.

4.2.2.2 Change of Direction

The ability too quickly and rapidly change direction is crucial in a football match in order to evade opponents while dribbling, with change of direction also being employed during the defensive phase of a match (Reilly *et al*., 2000).

Under 11's achieved a considerably slower performance than all other age groups, with the Under 13's and 15's players exhibiting a plateau in times. The similarity in times for the Under 13 and 15's, along with a lack of statistical significance and no practical effect size represents an important finding for the current study. No other studies have found a non-significant difference between age groups separated by 2 years (Vaeyens *et al.*, 2006; Le Gall *et al.*, 2008; Vanttinen *et al*., 2011; Lovell *et al*., 2015). Direct comparisons are difficult to make in agility testing - due to the varied testing procedures - but a common pattern is evident, as age positively impacts performance (Figueiredo *et al*., 2009; Gil *et al.,* 2014; Lovell *et al*., 2015).

A performance trend is evident for maturity stratification with the MO and pre-maturity offset groups having no significant difference, albeit with a medium effect size difference. However, more mature individuals, who did not differ from each other, outperformed less mature groups illustrating the effects of pubertal development.

The implications for why the performance trend for agility, acceleration, speed and aerobic capacity can be found in greater depth in section 4.3.

4.2.2.3 Acceleration

The attainment of speed in the shortest time possible is vitally important during a football match due to the unpredictable and dynamic nature of the game. Utilising change of direction and quick acceleration times will be of tremendous benefit to a youth athlete (Turner *et al*., 2011).

A similar pattern of performance is evident for acceleration results when compared to agility results as a non-significant difference occurred between Under 13 and Under 15 players. However, with times of 2.32 ± 0.21s and 2.23 ± 0.23, this did relate to a medium effect size difference indicating Under 15's outperformed their younger participants. Under 19's achieved the fastest performance with a time of 2.02 ± 0.23s but this is a slower than many younger players from European populations, with certain Under 13 and 14 teams being recorded with quicker times (Gissis *et al.,* 2006; Le Gall *et al*., 2008; Vanttinen *et al*., 2011; Lovell *et al*., 2015; Towlson *et al*., 2017).

When stratifying by maturity, performance level improves with more mature individuals completing the 10m sprint with times of 1.99 ± 0.15s and 1.97 ± 0.18s. However this would still not compare favourably to elite Qatarian players (Buchheit *et al*., 2013) and non-elite French players (Le Gall *et al*., 2008) of the same age or younger.

When investigating the trend of development it is evident that more mature individuals produce faster times, with little to distinguish individuals - effect size of 0.01 - past their maturity offset. Once again, performance for individuals experiencing and yet to experience their maturity offset did not differ significantly. Therefore, the maturational process caused faster acceleration times for youth athletes in the current study. If a players maturity status is not monitored on a regular basis an incorrect conclusion may be made about a youth players ability, especially in the current settings.

4.2.2.4 Speed

A high level of speed is required to out run opponents in order to create space for a player during a game scenario (Turner *et al.,* 2011). Furthermore, a team that completes the most number of sprints during a match has a greater chance of victory thus it is an integral part of a footballers arsenal (Turner *et al*., 2011).

Older players exhibited faster 30m sprint times in comparison to younger age groups. The effect size difference in time for the 30m sprint, between Under 19 and Under 15, was greater than the difference in 10m sprint time between the same age groups. An example being Under 19 to Under 15 and 13 age groups had an effect size of 1.14 and 1.84, while for 10m sprint the difference was 1.12 and 1.37. Interestingly the gap between Under 13 and Under 15 players was reduced with the greater sprinting distance. The Under 11s were considerably slower than all other age groups, as has been found with a predominance of all physical tests.

Age results were replicated in the maturity stratification as more mature groups produced significantly faster 30m and the time difference was statistically faster for the POST12 and POST24 groups. The least matured individuals completed the 30m sprint in a slower time while the maturity offset group performed between the less and more mature players. The PRE24 and PRE12 group had an effect size of 0.07 meaning results were negligible between individuals in either group.

Timings, as with acceleration, for all age and maturity groups, were much slower than populations of differing nationality notably English (Comfort *et al.*, 2013) and Finnish (Forsman *et al.*, 2016) players. Those of a higher playing level, elite Belgian players (Vadendriessche *et al.*, 2012), also outperformed the population sample. Additionally, younger participants managed to outperform the Under 19 players in the current population (Reilly *et* al., 2000; Vanttinen *et al*., 2011; Vadendriessche *et al.*, 2012).

The effects of maturation produced a significant impact on the time to complete a 30m sprint. Further, the difference in times between the older and youngest, and most and least mature, should indicate the difficulty in attempting to identify talented athletes at a young age.

4.2.2.5 Aerobic Capacity

The Yo-Yo intermittent run results were characterised by a similar level of performance for the Under 11, 13 and 15 groups. An average distance of 400m is not a substantial distance to be covered for these age groups and is classified as below average (Bangsbo, Iaia & Krustrup, 2008).

The increase in distance covered by the Under 19's, a gain of nearly 600m, is a substantial amount but the average distance of 1084 ± 584m is considerable lower than many previously recorded distances from players from Portugal (Figueiredo *et* *al*., 2009), Finland (Vanttinen *et al*., 2011; Forsman *et al.,* 2016), Belgium (Deprez *et al*., 2015) and Switzerland (Zubar *et al.,* 2016).

The POST24, and to a smaller extent the POST12, maturity groups also managed to complete a greater distance than less mature groups. As with age, the 3 least mature groups all completed a similar distance with no statistical significance between them and either a small or no effect sizes being present. The POST12 increase is interesting as it provides more information on the developmental pattern and specific periods of growth, which will be discussed in more detail. The large variability present is indicative of varying fitness levels and the relatively poor ability level of younger and less mature individuals.

Overall, both age and maturity positively impacted on Yo-Yo intermittent recovery test results and ultimately on aerobic capacity.

4.3 Potential explanatory factors of Performance

Possible contributing factors of poor performance are wide ranging with each population experiencing their own unique environments which shape and nurture athletes in different ways. Drawing upon the research of Tucker and Collins (2011) and Gagne (2004), among others, possible influences on performance may include; access and level of coaching, nutrition, socio-economic status, genetic inheritance, level of facilities, league or pathway structure, and amount and quality of practice time available. Ultimately, the inherent genetic traits a young footballer possesses must be combined with a high level of external factors in order to fully develop a young player. Of considerable importance to the current study is the socio-economic environment, poor health, nutrition and physical activity level as well as the access to coaching and facilities. Physical education is not widely taught to young South African players, especially in the tested population. A lack of competency in basic fundamental movements can have a severe impact on future athletic development. This would be an important area of future research to uncover in more detail the impact of poor physical education on soccer development in rural South African settings.

4.3.1. Socio-economic Environment

Low income can be classified by either ranking per capita monthly or yearly income, as well as from multidiscipline household questionnaires. Low income status is described by the Statistics of South Africa as less than R795 per person per month. While poor households can be calculated as earning less than R390 per person per month. A monthly income of R3668.60 ± 4468.60 ($250.03 ± 304.55), with an average family size of 5.1 ± 2.29, was present. This equates to an average of R719.21 for the current study population, although the variability present in income and family size will result in a small sample being ranked as medium income households.

Low socio-economic status has implications for youth development in terms of optimising performance due to the health risks associated with such an environment (McVeigh, Norris & de Wet, 2004; Jacobs & De Ridder, 2012; Uys *et al*., 2016). Additional studies, based on young black males, correlates poor socio-economic environment with a negative impact on an individuals natural anthropometric development, influencing height, weight, fat percentage and BMI (McVeigh, Norris & de Wet, 2004; Monyeki *et al*., 2006; Kruger & Pienaar, 2009; Pienaar & Viljeon, 2010; Jacobs & De Ridder, 2012; Toriola, Monyeki & Toriola, 2015; Armstrong, Lambert & Lambert, 2016).

Such factors may have played an important role in the development of the 150 participants in the current study. The current population perform poorly when compared against populations of different nationalities and ethnicities. A lack of stature and weight are indications of the influence poor socio-economic environment can have upon youth individuals, although care must be taken when interpreting results due to the potential genetic influence. Low socioeconomic status may have also impacted on the rate and timing of maturity, as evident with the current population experiencing a delay in their offset maturity date. A further knock on effect of later onset of maturity is similarity in results between Under 13 and Under 15 players which is not seen in any foreign populations. Socio-economic status may be a possible reason why total fat percentage was similar with demographic information outlining the environment many of these athletes experience (Rees *et al*., 2016). However, elite footballers had lower percentage of body fat and this speaks to the lack exposure to weekly physical exercise (Sherar *et al*., 2010).

4.3.2. Poor Health, Nutrition and Activity level

Black youth males have been found to be the most affected by poor nutritional intake (Armstrong, Lambert & Lambert, 2016). Fat percentage values attained in the current study are symptomatic of the current climate with a large disparity between underweight and overweight individuals. No studies have investigated the maturity status and development of black youth males but a low BMI has been present for all chronological age groups (Armstrong, Lambert & Lambert, 2016). This presents a clear rational for the low body fat level and poor weight and BMI classification in young black South Africans present in the study. Poor health, nutrition and level of physical activity exposure will also have a negative impact on the physical capabilities of youth athletes as evident by the current findings.

South Africa also received a poor grade for overweight and undernutrition levels in youth individuals, this was recorded as a D grade in the National Health Report (Uys *et al*., 2016). Differences were most common between urban, high socio-economic areas and rural or urban, low socio-economic areas such as townships (Armstrong, Lambert & Lambert, 2016; Uys *et al*., 2016). Participants in the current study can be classified as low socio-economic urban dwelling areas while the disparity in weight between tested individuals supports the argument for poor nutrition, although further study is required to accurately quantify nutritional intake.

In a South African national health study, conducted in 2014 and 2016, activity level of youth individuals was given a D grade (Uys *et al*., 2016). Physical fitness and motor proficiency, along with organised sport participation, received the same grade (Uys *et al*., 2016). The lack of access young individuals have to well set up sporting programmes, and the low level of physical literacy present, pose a problem for youth talent development and identification moving forward (Uys *et al*., 2016). Additionally, school physical education also received a D grade with many schools cutting PE time from their curriculum (Uys *et al*., 2016). Results indicate that a similar outcome is present for the studied population who report low levels of weekly physical activity. Participants indicated they spent 8 hours a week involved in football specific activity with a range of ±4 hours a week. Further research is required to fully quantify the level of physical activity but the poor results indicate a potential deficiency.

The local football association present in the Makana municipality is one of hundreds, as seen in section 1.2.9.2, with it being part of the 5th level of the footballing pyramid. It is a completely amateur division with limited funding present for teams to utilise. In combination with the poor socio-economic standing of the region, section 1.2.9.1 along with reported demographic information, suggests players of all ages compete for enjoyment of the game rather than expecting to compete at an elite level.

It is therefore likely the LFA soccer players in the Makana region experience poor socio-economic conditions which can lead to their nutritional intake being affected, a lack of physical activity, further impacting on their anthropometrical characteristics and their physical abilities. Further studies looking at the implications of these findings is necessary to elucidate possible causative factors in more detail.

4.3.3. Access to Poor Coaching & Facilities

A lack of facilities and coaching may have prevented younger players from having access to adequate physical education. Poor facilities have been noted by SAFA, as well as reported in various studies conducted on populations nationwide (SAFA Technical Masterplan, 2012; Coopoo *et al.*, 2012). Facilitates in South Africa are either too far, unsuitable or there is a complete absence of facilities, have been poorly managed and no longer offer the requisite level of support and opportunity (Uys *et al*., 2016). The closest geographical facilities to the participants was not of satisfactory standard for scientific testing. A singular training ground is present for all teams within the municipality with minimal maintenance being performed. The quality and quantity of training may be affected with participants unable to routinely practice causing the decrease seen in the physical results.

Additionally, a lack of coaches, and the level of qualification they hold, will result in less exposure to quality physical education (Coopoo *et al.*, 2012). A coach is often expected to conduct many roles for multiple age groups all with minimal training and expertise (SAFA Technical Masterplan, 2012; Coopoo *et al.*, 2012). Coaches of the teams tested, each held multiple roles with only 1 coach being available for all age groups as well as being responsible for senior teams. A recent study - unpublished by the present research group - highlighted the lack of coaching qualifications obtained by coaches within the Makana LFA.

4.4 Implications of Results

4.4.1. Puberty development & Delayed Peak Height Velocity

The importance of peak height velocity and the meaningful impact puberty has on athletic development is evident from the current study. The sudden jump in athletic development, from maturity offset to individuals 12 months past this point, is caused by individuals experiencing their peak height velocity (Bailey *et al.,* 2010; Ford *et al*., 2011; Towlson *et al*., 2018). Additionally, the large increase in weight after the age of 15 signifies peak weight velocity (Viru *et* al., 1999; Naughton *et al.,* 2000; Rogol, Roemmich & Clark, 2002).

The average age of maturity onset was delayed in the current population when compared to normal pubertal development (Naughton *et al.,* 2000; Rogol, Roemmich & C lark, 2002). The age of onset was 14.9 years and this is later than other footballing populations from Belgium (Philippaerts *et al.,* 2006; Deprez *et al*, 2015), Portugal (Figueiredo, Coelho e Silva and Malina, 2009), Spanish (Gil *et al.,* 2014),,and England (Lovell *et al.,* 2015; Towlson *et al*., 2018).

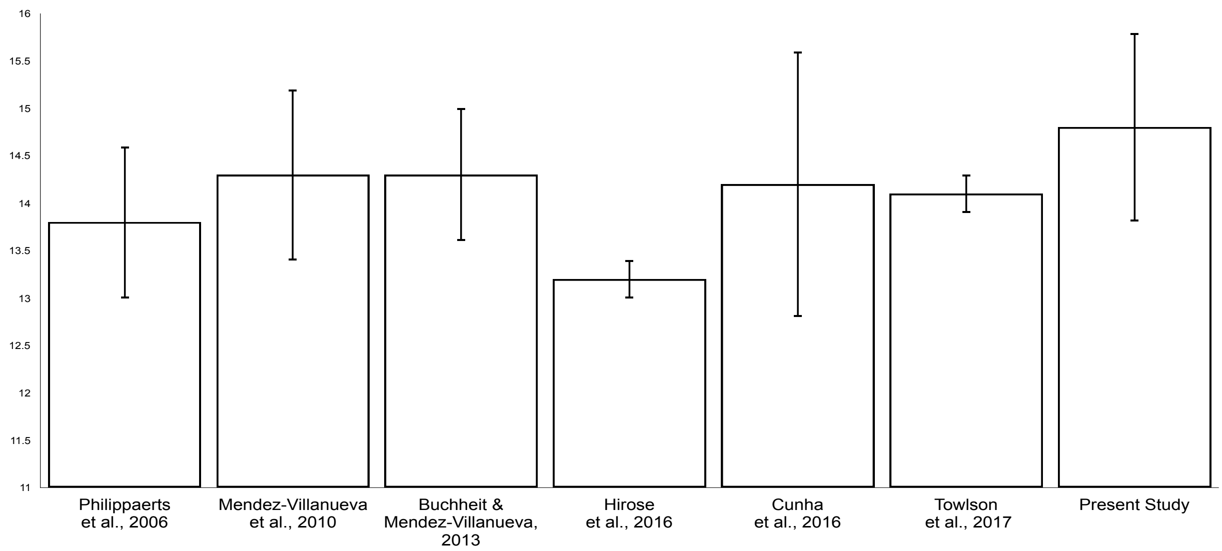


Figure 24. The ages which different study populations experience their Peak Height Velocity compared against the present Study

Cole *et al.,* (2014) detailed the maturity rates of young black South African males and found they were approximately 7 months later than white males falling in line with the current study findings. Further comparative studies are needed before definitive conclusions can be made but it can be suggested that the present socio-economic environment has a negative impact on the rate and timing of maturity in youth South African footballers (McVeigh, Norris & de Wet, 2004; Monyeki *et al*., 2006; Armstrong, Lambert & Lambert, 2016).

During peak weight and height velocity, power and strength gains are made along with better coordination, speed, acceleration and cardiovascular capabilities resulting in improved performance across all domains (Malina *et al*., 2000, Le Gall *et al*., 2008; Buchheit, Mendez-Villanueva and Bourdon, 2010; Ford *et al.,* 2011; Lovell *et al*., 2015; Towlson *et al*., 2018). The added stature, muscle and hormonal development provides additional capacity to outperform less mature peers (Bailey *et al*., 2010; Ford *et al.,* 2011; Lloyd *et al.,* 2016). A delayed average time to the onset of maturity will mean any windows of trainability will occur later on for the current participants. Thus training plans would have to be adapted from overseas population samples and more patience is required when waiting for athletes to fully develop physically.

4.4.2. Poor Overall Performance in Tests

Overall, many of the results can be considered poor when compared to normative data or to players from different ethnicities, nationality and playing level. Although the current population is a non-elite cohort the difference in values is stark, as comparisons to other non-elite studies indicate youth South African players still perform poorly. The current cohort of players were selected from the Local Football Association League which is representative of the SAFA talent identification and development program. Therefore, data on these players is vital in informing the quality of the program in terms of providing players with appropriate training environments to improve physical capability skills. The findings of the current study are concerning in this regard as it is evident that the LFA players are performing at lower levels than those in other contexts. Youth South African footballers did not outperform other study populations in any tested component. Poor test results will ultimately impact on the quality and level of play and further investigation is needed to quantify the extent to which this may occur.

4.4.3. Talent Identification, Selection & Development.

An implication of the current study results is that determination of an individuals talent level at the age of 10 or 11, is misleading as a substantial increase in performance is evident only after the age of 15. The Under 19's outperformed all age groups, although this is to be expected as players above the age of 16 would have reached maximum height and finished their developmental process resulting in increased performance (Rogol, Roemmich & Clark, 2002; Bailey *et al.,* 2010; Buchheit *et al*., 2010; Ford *et al.,* 2011; Towlson *et al*., 2018). Along with maturity development, picking a talented player at a young age gives no guarantee they will maintain their ability level as the difference in results between youngest and oldest, and least and most mature players, is too significant.

Care should be taken to ensure players are properly monitored every few months to better understand their developmental rate. Consequently, if coaches do not understand this and follow a traditional model of talent development those that have matured quickest may receive more playing time. However, further research is needed to investigate if such a scenario occurs within the league structures current players compete in.

As described in section 1.2.9 on the contextualisation of the the present research area, numerous problems are present within the South African Football Association. A lack of qualified coaching, poor facilities and infrastructure, a lack of adequate talent pathways in conjunction with the economic situation of the Makana region create a situation in which effective talent development is difficult. A low socio-economic environment presents obstacles which hinder development and this is present in the current study population. A Long Term Athletic Development model is proposed by SAFA to develop youth footballers and it is expected that LFA's contribute players towards the professional ranks. In order for this pathway to be effective all the above mentioned problems would have to be rectified. Results indicate that study participants are currently below the talent level from populations in different contexts and this a result of a complex array of factors. The inherited genetic abilities, the anthropometric, physical, psychological and technical gifts, characteristics and abilities and athelte might possess, as well as the lived socio-economic environment (Rees *et al.,* 2016). Furthermore the provision of coaching, league structures, practice time and support programs all have an influence (Rees *et al.,* 2016).

If players from LFA's exhibit poor anthropometric characteristics and physical ability levels this will have implications for talent development pathways. However tactical related cognitive capabilities, personality traits and technical ability are also important aspects to consider. Delayed onset of maturity reduces the time available to optimise certain physical components again comprising the effectiveness of talent development pathways in South African football. The low socio-economic area many of the LFA's operate in result in an inability to correct the problems present within their leagues and clubs. Ultimately, young players are negatively impacted by their environment and the lack available resources has reduced their capacity to perform.

CHAPTER V: SUMMARY, LIMITATIONS, RECOMMENDATIONS & CONCLUSION

5.1. Purpose of Study

Little to no information is available on the anthropometric and physical abilities of youth South African footballers. Detailing this information may influence the implementation of training strategies while also providing a clearer understanding of the strengths and limitations present in young South African players. The impact of maturity, and the possible environmental constraints, on youth athletes is important to quantify. Therefore, the aim of this study was to determine the age and maturity specific changes to anthropometric characteristics and the physical capabilities of youth South African footballers in the LFA structures in Makana, Eastern Cape province.

5.2. Summary of Procedures

Four anthropometric measures (Height, Weight, Body Mass Index and total fat percentage) along with five physical measures (Power, agility, acceleration, speed and endurance) were tested on a total of 136 youth footballers recruited from the local league structure. Each participant performed all tests within 2 sessions along with the completion of a basic demographic and football-related questionnaire. All anthropometric and physical measurements were recorded 3 times, apart from the YO-YO Intermittent Run, to ensure accuracy and reliability. Players first conducted the anthropometric measures and then completed a standardised warm-up followed by the physical tests according to sport science testing standards and order. Specific equipment was utilised for the necessary tests to ensure accuracy was maintained.

5.3. Summary of Results

Significant differences were found between all anthropometric results when stratified by age and maturation with total fat percentage being the only non-non-significant finding. For physical results significant differences were found between age groups for all tests. The main outcome was the similarity of results between the Under 13 and Under 15 players when stratified by age. The POST12 group had significantly better performance than the maturity offset group with large effect sizes present. The oldest and most mature age groups produced the best physical results and were also the tallest and heaviest.

5.4. Response to Hypotheses

Hypothesis 1: The null hypothesis stated that no significant differences will be found for anthropometric and physical characteristics when stratified by age. The null hypothesis is rejected for every tested components apart from total fat percentage whereby the null hypothesis is accepted.

Hypothesis 2: The null hypothesis stated that no significant differences will be found for anthropometric and physical characteristics when stratified by puberty. Once again, all tested components where rejected apart from total fat percentage which accepted the null hypothesis.

5.5. Limitations

5.5.1. Issues with Players

The difficulty in organising and transporting the individuals to the testing sites was a concern with recruitment of participants. Communication was facilitated by coaches but their access to players was limited. Players could only be told of testing sessions at practice, which was also a struggle to arrange due to poor facilities present, with a low number of participants having access to a telephones or mobile device. Transportation had to be arranged to collect and drop off players as many did not have access to their own transportation as reflected in the 88% that walked to school. This also meant testing sessions were at different times of the day to accommodate large groups of participants.

Participants were also unfamiliar with many of the tests implemented. An adaptation period was provided but players had had limited exposure to such testing methodologies. This could also have been influenced by the lack of communication between the tester and players, as many individuals spoke isiXhosa as their main language and the tester spoke English. A particular difficulty was found with the Yo-Yo Intermittent Run as players had no experience of the test and multiple test runs were needed before players fully grasped the test. Additionally, the concept of maximal exertion may not have been conveyed nor the importance of doing so to establish correct results. It was noted that individuals often ended their participation in the Yo-Yo test before they had reached this point which may have impacted the end result. Additional sessions and exposure to maximal testing over a longer time period is warranted. Multiple habituation sessions are required before participants can fully understand the techniques involved in each test and the requisite maximal exertion level.

5.5.2. Issues with Testing Equipment and Methodology

The Slaughter equation for body fat have not been validated extensively on a Black South African children. Therefore, variations might be present in final results as indicated by the high body fat percentages found in Figure 9A.

Sample Sizes for each age and maturity groups were uneven with varied sample numbers present. Ideally a minimum of 20 players per age and maturity group would have been ideal to allow homogeneity of variance to potentially be established. The low number of participants in the maturity offset (16), POST12 (10) and POST24 (15) as well as the difference in total participants between stratifications is not ideal. However, the nature of recruitment made this difficult due to the issues raised in section 5.5.1.

5.6. Recommendations

Recommendations are as follows for future testing and direction of study:

- Longitudinal testing is required to create a clearer understanding of individual development curves and the intra-individual difference present between participants. The current cross sectional study gives a basic overview of where potential weaknesses and strengths are but a more in-depth, longitudinal study will allow the issues of PHV to be explored. Testing would also allow greater exposure to the various testing methods and more familiarity with the different tests will allow a better reflection of youth South African footballers natural talents to be expressed.

- Further analysis of the pubertal development curve for youth black males is required. Peak height velocity is a validated non-invasive method broader longitudinal studies are needed, on both males and females, which identify the development rate and timing. This would allow greater specification for training programs and allow the alignment of physical and talent development models such as the LTAD or YDP to be better connected to the South African population.
- The impact of the socio-economic setting on personality and football related tactical skills would also be an interesting study to undertake due to the large mental load football places on players. Again, no studies, to the authors knowledge, have attempted to quantify this variable within the South African population and in order to provide a holistic understanding of the youth footballing population this would be needed. In conjunction, the testing of technical skills should also be investigated in order to complete the necessary components. How these each of these components develop over time and the interaction effect between anthropometric, physical, technical, tactical and personality attributes would illuminate why South African football experiences its various problems.
- The use of small sided games and appropriate football specific testing should be utilised. The breakdown of components into testable areas is useful but a more realistic setting might provide more context to where youth players are struggling. Most importantly will be the impact of fatigue, as this was not assessed in the current study. How physical, mental and technical attributes change when a player fatigue is an important question which has not been addressed fully in the current literature.
- Further work is required to establish the complex problems present within the Makhanda LFA and how the systems currently in place influence the talent identification and development pathways. A systems approach to identify the external and internal factors, and most importantly, the relationship between all factors is vitally important. As a basis, Gagne’s (2004) DMGT outlines the important areas to be considered for analysis.

5.7. Significance of Findings

The average age of maturity in the current population, with an onset age of 14.8, is considered to be delayed. The lack of significance between total fat percentage also points towards the socio-economic environment present. The delayed maturity, low weight, reduced stature and low total fat percentage are all indications of problems brought on by a range of factors mostly influenced by socio-economic standard. Furthermore, the physical results were also substandard when compared to populations of different nationality and ethnicity. The differences in the pubertal development of youth African footballers has implications for future athletic development with a potential causation mechanism being the present socio-socio-economic environment many athletes experience.

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APPENDIX A

A.1. INFORMATION TO PARTICIPANT

LETTER TO PARTICIPANTS

RHODES UNIVERSITY

DEPARTMENT OF HUMAN KINETICS AND ERGONOMICS

Dear (Mr)…………………………………………………………………..

Thank you for showing an interest in the research project:

"Soccer specific physical and anthropometric characteristics of South African Youth Footballers"

The study shall take place at Rhodes University at the Department of Human Kinetics and Ergonomics (HKE) and will be conducted by a current Masters student of the HKE Department.

There is currently a lack of information on Sub-Saharan Africans within a footballing context in terms of anthropometric status, physical performance as well as technical skill level. Without these data it is not possible to develop appropriate programs for the identification and development of youth South African footballers. Furthermore the barriers preventing youth players from making it to an elite level are not yet known or the extent to which they are modifiable. A holistic investigation of the various factors affecting performance will help to provide this very important information. Further, by testing a range of ages a more precise timeline of development can be produced. Each component has been shown, through extensive research, to play an important role within a football match.

Project Protocol Procedure

Participation is completely voluntary and, at any point after consent has been given, you may withdraw. No formal reason or explanation will be necessary. During the testing battery, you may stop at any time if you are experiencing any form of pain or discomfort. You will also not be disadvantaged in terms of team involvement if you choose not to participate in the study.

Participants will be assessed over 3 different testing sessions.

Session 1

The first session will be used to recruit and inform participants. You will be given the opportunity to ask questions after an overview of the current study and each component. In addition demographic data, such as age, schooling and family information will primarily be used to identify your socioeconomic status. Furthermore, your past footballing history will also be taken as well as establishing dates for testing.

Session 2

The second session will focus on collecting anthropometric data and conducting the physical testing battery.

Anthropometric data will include measurement of height, weight, lean body mass and peak height velocity. Lean body mass will be measured using a skin fold calliper to measure total body fat. This data, along with peak height velocity measurements, will give an indication of biological maturity.

The physical testing battery will consist of 4 different sections. These are aerobic capacity, acceleration and speed, power and agility. Each player will be provided with 3 attempts with the average value used for each test apart.

- Aerobic capacity will be tested using the Yo-Yo Intermittent Recovery (YYIR) run. Depending on your age you will either complete the Level 1 or Level 2 YYIR run.
- Acceleration and speed will consist of a 40-meter sprint with timing gates positioned at the 10m point. Each footballer will need to complete the sprint in the shortest time possible.

- Power will be measured using the vertical and countermovement jump test. You will be required to perform a maximal jump in an attempt to reach the highest point possible.
- The Illinois agility run is a validated measure of agility. Each participant has to complete the set course in the shortest. The course consists of a number of changes in direction and movements that have to be correctly executed for the time to count.

Risks and Benefits

Risks: There are limited risks in participating with this study. The physical testing battery consists of movements that are commonly repeated within a training session or match. The only section that may be of injury risk is during the physical testing, as this requires maximal effort thus increasing the potential for muscle injuries. Care will be taken to ensure that you are adequately warmed up before participating in either session.If you do not feel comfortable participating in a large group a singular session can be arranged. Furthermore, each coach has agreed that your position in the team will not be affected if you choose not to participate in this research project.

Benefits: The benefits to participating in this study centre around having a greater understanding of your own abilities. The study will provide you with a benchmark of where your current performance characteristics are and the areas in which we can work to further develop your skills going forward. Further you will also gain a greater knowledge about the different components that constitute footballing ability and how they may be influenced.

Archived info, anonymity and feedback

All participants will be coded thus outside sources may not be able to readily identify you or your personal information. Data will be stored and participant may request it at any time. Only the researcher and supervisor will have access to the data. All data presented in the final thesis will be summary data with no possibility of individual data being traced back to participants.

Once the study is completed, each participant will have access to overall findings and upon request a report can be written for individuals pertaining to their performance and any possible injury risks.

Requirements

Before each session please follow the below guidelines:

- Please do not consume the following items 3 hours before each session: caffeine and tobacco
- Please do not complete any form of strenuous exercise 24 hours before session 1 and 2
- If possible wear unrestrictive clothing suitable for soccer.
- Please inform if there are any health status changes and medication intake.

Thank you for choosing to participate in my thesis; if you have any further questions please contact me.

Ashley De Beer Phone: 076 035 7907 Email:ashleycdebeer@gmail.com

Andrew Todd Phone: 083 277 0795 Email:a.todd@ru.ac.za

A.2. INFORMATION TO GUARDIAN

LETTER TO PARENTS OR GUARDIANS

RHODES UNIVERSITY

DEPARTMENT OF HUMAN KINETICS AND ERGONOMICS

Dear (Miss/Ms/Mr)…………………………………………………………………….

Thank you for allowing your child to participate in the research project:

"Soccer specific physical and anthropometric characteristics of South African Youth Footballers"

The study shall take place at Rhodes University at the Department of Human Kinetics and Ergonomics (HKE) and will be conducted by a current Masters student of the HKE Department.

There is currently a lack of information on Sub-Saharan Africans within a footballing context in terms of anthropometric status, physical performance as well as technical skill level. Without these data it is not possible to develop appropriate programs for the identification and development of youth South African footballers. Furthermore the barriers preventing youth players from making it to an elite level are not yet known or the extent to which they are modifiable. A holistic investigation of the various factors affecting performance will help to provide this very important information. By testing a range of ages a more precise timeline of development can be produced. Each component has been shown, through extensive research, to play an important role within a football match.

Project Protocol Procedure

Participation is completely voluntary and, at any point after consent has been given, you may withdraw your child. No formal reason or explanation will be necessary. Your child will also not be disadvantaged in terms of team involvement if you or they choose not to participate in the study.

Participants will be assessed over 3 different testing sessions.

Session 1

The first session will be used to recruit and inform participants. You will be given the opportunity to ask questions after an overview of the current study and what each section requires. In addition demographic data, such as age, schooling and family information will primarily be used to identify your child's socioeconomic status. Furthermore, your child's past footballing history will also be taken as well as establishing dates for testing once consent has been given.

Session 2

The second session will focus on collecting anthropometric data and conducting the physical testing battery.

Anthropometric data will include measurements of height, weight, lean body mass and peak height velocity. Lean body mass will be measured using a skin fold calliper to measure total body fat. This data, along with peak height velocity measurements, will give an indication of the biological maturity of your child.

The physical testing battery will consist of 4 different sections. These are aerobic capacity, acceleration and speed, power and agility. Each child will be provided with 3 attempts with the average value used for each test apart.

- Aerobic capacity will be tested using the Yo-Yo Intermittent Recovery (YYIR) run. Depending on your child's age you will either complete the Level 1 or Level 2 YYIR run.
- Acceleration and speed will consist of a 40-meter sprint with timing gates positioned at the 10m point. Each footballer will need to complete the sprint in the shortest time possible.

- Power will be measured using the vertical and countermovement jump test. Your child will be required to perform a maximal jump in an attempt to reach the highest point possible.
- The Illinois agility run is a validated measure of agility. Each participant has to complete the set course in the shortest. The course consists of a number of changes in direction and movements that have to be correctly executed for the time to count.

Risks and Benefits

Risks: There are limited risks in your child participating with this study. The physical testing battery consists of movements that are commonly repeated within a training session or match. The only section that may be of injury risk is during the physical testing, as this requires maximal effort thus increasing the potential for muscle injuries. Care will be taken to ensure that your child is adequately warmed up before participating in either session. If your child does not feel comfortable participating in a large group, a singular session can be arranged. Furthermore, each coach has agreed your child's position in the team will not be affected if you choose not to participate in this research project.

Benefits: The benefits to participating in this study centre around having a greater understanding of your child current abilities. The study will provide you with a benchmark of where your child current performance characteristics are and the areas in which we can work to further develop your skills going forward. Further you and your child will also gain a greater knowledge about the different components that constitute footballing ability and how they may be influenced.

Archived info, anonymity and feedback

All participants will be coded thus outside sources may not be able to readily identify you or your personal information. Data will be stored and participant may request it at any time. Only the researcher and supervisor will have access to the data. All data presented in the final thesis will be summary data with no possibility of individual data being traced back to participants.

Once the study is completed, each participant will have access to overall findings and upon request a report can be written for individuals pertaining to their performance and any possible injury risks.

Requirements

Before each session please ensure your child follows the below guidelines:

- Participants should please not consume the following items 3 hours before each session: caffeine and tobacco
- Participants should please not complete any form of strenuous exercise 24 hours before session 1 and 2
- If possible each player wear unrestrictive clothing suitable for soccer.
- Please inform if your son/player has any health status changes or medication intake.

Thank you for choosing to participate in my thesis; if you have any further questions please contact myself or my supervisor.

Ashley De Beer Phone: 076 035 7907 Email:ashleycdebeer@gmail.com

Andrew Todd Phone: 083 277 0795 Email:a.todd@ru.ac.za

A.3. INFORMATION TO GUARDIAN & CONSENT FORM - ISIXHOSA TRANSLATION

Imbalelwano Yabo Bazakuthath Inxaxheba
RHODES UNIVERSITY
ISEBE LE HUMAN KINETICS AND ERGONOMICS

Bota (Mnumzana)…………………………………………………………………
Enkosi ngokubonakalisa umdla koluphando mfundo:

“Sifuna ukwazi indlela abadlala ngayo nempawu esithi sizibone ngokwasemzimbeni kubadlali abaselula bebola ekhatywayo balapha eMzantsi Afrika”

Olufundo luyakuthi lwenzeke eRhodes University kwiSebe leHuman Kinetics and Ergonomics (HKE), luzakuqhutywa ngomnye wabafundi bemfundo eneziqu kweliSebe leHKE.

Kusekho ukusilela kolwazi kuthi maAfrika aseMazantsi eboleni ekhatywayo ngokubekisele kwi ANTHROPOMETRIC STATUS ,PHYSICAL PERFORMANCE kunye neqondo lesakhono sokudlala ibola. Ngaphandle kobubucukubede asingeze sikwazi ukuqulunqa inqubo ezifanelekileyo ezizakuthi zalathe , zichonge kwaye ziphuhlise isakhono sokudlala ibola kulutsha lwaseMzantsi Afrika .Ngaphezulu koko imiqobo ethintela abadlali abaselula ukuba bangakwazi ukuyakudlala kwinqanaba eliphezulu ayikaziwa okanye indlela esinokuthi itshintshwe ngayo. Uphando oluvelela zonke inkalo nemicela mngeni eyahlukileyo echaphazela ukudlala ,lunganceda ekunikezeleni ulwazi olubalulekileyo .Kwaye senze novavanyo kubadlali abaneminyaka eyahlukahlukeneyo ngaxeshanye ukwenzele sizokwazi ukuba nexesha, umnyaka neyanga awaqala ngalo ukuphuhliswa .Yonke lento ingentla nganye nganye iye yabonakala emveni kwenziwe uphando fundo oluluqilima olubonakalise ukuba zonke zibalulekile nxa kudlalwa umdlalo webola ekhatywayo.

Inqubo Mgaqo yeProject
Inxaxheba ithathwa ngamavolontiya naninina emveni kokuba kuvunyelwene angakwazi ukurhoxa. Akukho sizathu okanye ingcaciso ifunekayo. Ngexesha lovavanyo ungayeka naninina nxa ungaziva kakuhle okanye usiva intlungu .Ukuba ucinga ukungathathi nxaxheba kulungile,lonto ayizokubangela into yokuba ungabi yinxalenye yeqela lakho .
Abathathi nxaxheba bazakuphononongwa izihlandlo ezithathu ezahlukileyo.

Isigaba sokuqala

Isigaba sokuqala sizakutyenziswa ekuqokelelni nasekucaciseleni abo bazakuthi bathathe inxaxheba. Uzakunikwa ithuba lokuthi uzibuzele imibuzo emveni kokuhlalutya olundo ,kunikezelwe ngengcaciso nganye nganye.Ukwangeza nenkcukacha malunga nobume into ezifana iminyaka,isikolo nenkcukacha ngosapho lwakho nto leyo eyakusetyenziswa ukuqikelela ubume bakho kwezoqoqosho.Ngaphezulu koko imbali yakho yebola nayo izakuthathwa nentsuku oqale ngazo uvavanyo.

Isigaba sesibini

Isigaba sesibini sakube sijongene nokuqokelela inkcukacha ngokubekisele emzimbeni(anthropometric data),nomzimba uvavanywe ilahle(testing battery) .

Ezinkcukacha ngomzimba wakho zizakubandakanye ubude ,ubunzima ,ubudweni kwaye inike negqwalasela kwixesha apho ukhula khona kakhulu .Ukutyeba okanye ukuncipha komzimba kuyakuthi kusetyenziswe izixhobo zenzulu lwazi zalemihla ,ukuzama ukujonga ukuba umzimba wakho unefutha elingakananina.Ezinkcukacha zinganikezela ingcaciso ethe vetshe ngokubekisele ekukhuleni nokuthi leliphi elona xesha apho khona uthe wakhula kakhulu.

- Oluvavanyo ngokwasemzimbeni luyakube lahlulwe laziziqendu ezine ezahlukileyo.Ngezi zilandelayo umxhelo, isivinini,amandla kunye nomthambo. Wonke umdlali uyakunikwa ithuba izihlandlo ezintathu kujongwe indlela oqhube ngayo kwaye ,abadlali bayakulinikwa ixesha lokuphumla phambi kokuba bagqithele kwenye.Umxhelo uyakuthi uvavanywe kusetyenziswa ezenzulu lwazi (YYIR) ekubalekeni.Ixhomekeke kwiminyaka yakho ukuba ungakwazi ukwenza isigaba sokuqala okanye esesesibini (YYIR).
- Ukubaleka kakhulu umgama ozimitha ezingamashumi amane ungene phakathi kwesango ozabe ulibekelwe,ongena kwakho bazakujonga ixesha olibalekileyo. Wonke umdlali kuyakufuneka azame ukuwubaleka lomgama ngexesha elincinci kakhulu.
- Amandla wona ayakuthi avavanywe ngokuthi kucitywe ngentlobo ezithile ezahlukahlukeneyo.Kufuneka wenze owona mtsi wakhe wamde okanye utsibe phezulu kangangoko unako .

(The Illnois agility),Oluhlobo lokubaleka lujijojiko lunika ingqwalasela kwindlela ojika ngayo mnsinyane ,wonke umntu ulindeleke ukuthi agqibe msinyane iseti yakhe.

Isigaba sesithathu

Esi isigaba sesokugqibela sesokuvavanya isakhono sokudlala. Kulandele ukushushubeza umzimba, uzakucelwa wenze oluvavanyo lulandelayo .Ingcaciso ethe vetshe izakunikezelwa nethuba lokuba uzikhangele phambi kokuba uqale ,ude uqhele kwaye uzethembe wazi nokulindelweyo kuwe kuvavanyo ngalunye.

- Ukukhaba ngokuchanekileyo umgama wemitha ezingamashumi amane .
- Ukukhaba ibola ehamba phezulu ngokuchanekileyo ihambe umgama onaphaya kwamashumi amathathu anesihlanu.
- Uvavanyo lokukhaba ngamandla ngokuchanekileyo kwiqono 135 degrees
- Uvavanyo lokukhabela umdlali wakho ngendlela ecanekileyo
- Ukutyisa ngendlela ekhawulezileyo (dribbling speed)
- Sijonge nendlela oteka ngayo ibola
- Ukukhaba ibola ngokukhawuleza ulijike 90 ngokweqondo
- Ukujika ibola uyikhabe kwiqondo elingu

Okunokuthi kusibeke esichengeni okanye okunokuthi kube lulutho

Okusibeka esichengeni: Anciphe kakhulu amathuba okonzakala nxa uthatha inxaxheba kolufundo. Zombini ezizigaba zovavanyo ngokwasemzimbeni, nasekudlaleni zigqale nqo kwintshukumo othi uzenze kumdlalo kuphiswano naxa uzilolonga. Esona sigaba sinongcipheko wokufumana umonzakalo kuxa sisenza uvavanyo lomzimba,njengokuba umzimba uzakube uphantsi koxinzelelo lonto ingachaphazela izihlunu zomzimba.Ingqwalasela iyakunikezelwa kungakumbi phambi kokuqala oluvavanyo ,siyakuqinisekisa ukuthi umzimba ukulungele ukuqala ,sakuthi siqale ngokushushubeza umzimba ngokufaneleyo. Kwisigaba sebola ekhatywayo siyakuqinisekisa ukuba uqale wazilungiselela ngokwaneleyo kwaye uyayazi ukuba kufuneka wenze ntoni phambi kokuba uqale.Ukuba ubani uthe akafuna ukwenza nesininzi, sakuthi simenzele ixesha akwazi ukuzenzela eyedwa.Ukongeza ,ukuba umdlali akafunanga ukubayinxalenye yolufundo phando lonto ayisoze imbangele ukuba angabi yinxalenye yeqela.

Okulululutho:Ukuthatha inxaxheba kolufundo phando kungakwenza iyakwenza ukuthi uzazi ukuba udlala njani ,umzimba wakho ukweliphi iqondo,wazi nokuba iakhono sakho sikweliphina inqanaba ngezihpi izinto ekufanele unyuse ikawusi kuzo uzobangumdlali osemandleni .Uyakuthi ufumane nolwazi oluphangalelyo ngezinto ezahlukileyo ezidlala indima enkulu ekuphuculeni izakhono kumdlalo webola ekhatywayo.

Inkcukacha nengelo zolufundo phando ,luyakuba yimfihlelo

Abadlali ababathatha inxaxheba bayakuthi banikwe amagama/amanani aziwangabo bodwa ukwezela ukuba inkcukacha zomntu zaziwe nguye yedwa .Zonke inkcukacha eziqokelelweyo ngomdlali ngamnye ziyakuthi zifumaneke ukuba yazifuna. Iyakuba ngumntu oqhuba olufundo phando nomphathi wakhe abakuthi babone izphumo

zophando .Konke okuyakuthi kukhutshwe kwi thesis, iyakushwankathelwa ngendlela apho ubani engeze azi nokuba kuthethwa ngabani, ukuzama ukukhusela isidima sabo bebe thathe inxaxheba.
Ekugqityweni kolufundo phando wonke umntu ebethathe inxaxheba uvumelekile ukuba azifumane iziphumo zophando.

Okufunekayo
Phambi kokuba uthathe inxaxheba uyacelwa ukuba ulandele imiyalelo

- Uacelwa ukuba ungatshayi ,ungaseli nekofi kwi yure ezintathu phambi kokuba uthathe inxaxheba
- Uyacelwa ukuba ungasebenzi nzima kwiyure ezingamashumi amabini anesine phakathi kwe isgaba sokuqala nesesithathu
- Uyacelwa ukuba unxibe impahla zokudlala ibola ekhatywayo
- Xela ukuba utya amayeza kagqirha okanye awuziva kamnandi

Enkosi ngokuthatha inxaxheba koluphando mfundo ,ukuba unemibuzo nceda undithinte kulenombolo ilandelayo

Ashley De Beer :076 053 7907 Email:ashleycdebeer@gmail.com
Andrew Todd : 083 277 0795 Email:a.todd@ru.ac.za

Imvume YOMZALI/UMQEQESHI/UMNTU Ogcina umntwana
Mna……………………………………………………………………………ndiyavuma ukuba ……………………………………………….........ukuba angathatha inxaxheba kuphando ngokwezemfundo “Impawu nendlela Ulutsha lwase Mzantsi Afrika abadlala ngayo ,sijonge nqo ngokwasemzimbeni’’

Ndazisiwe malunga ne ntsingiselo yolufundo phando kwaye ndazisiwe ngakokonke umntwana /umdlali anothi agaxeleke kuzo umzekelo ukunzakala ,ndikwazisiwe kwananjalo ngokubalulutho emntwaneni/emdlalini .Akhonto iyimfihlo izphumo zoluphando mfundo nenqubo yakuthi abo baththe inxaxheba baziswe ngomlomo okanye ngento ebalwe phantsi. Nje ngoMzali/Mqeqeshi ndiyayazi okulindelekileyo emntwaneni/mdlalini ngokubekisele ekuthatheni inxaxheba ngokuzimisela nokuzinikela koluphando mfundo.

Ngokuvuma ukuthatha inxaxheba koluphando mfundo ndikwathatha uxanduva kunye necandelo le HKE ukuba ndinothi ndifumane umonzakalo .Andisayikuthathela umphandi mfundi okanye iRhodes University amanyathelo omthetho ,kwaye ndikwathatha uxanduva ukuba ndizondzakalisile mhlawumbi awulandelanga imiqathango ngendlela efanelekileyo.Ndiyavuma/qonda ukuba umntwan/umdlali angayeka ukuthatha inxaxheba ukuba akaziva kamnandi okanye uva ubuhlungu noba yinto engamenzi azive kakuhle .Ndikwayazi kananjalo ukuba nokuba umntwana/umdlali wam akathathanga nxaxheba kolufundo phando useyinxalenye yeqela.

Ndiyayazi ukuba zonke inkcukacha ezakuthi zithathwe koluphando mfundo ngomdlali/mntwana ziyakuba yimhlihlelo ,kwaye ndikwavuma ukuba lonke uphando okanye iziphumo zisetyenziswe koluphando mfundo.Ndiyavuma ukuba bangathathwa ifoto kodwa ukuba kunempawu endingafuni zivele azizovezwa .

Ndiyifundile kwaye ndiyayazi ukuba ezinkcukacha zingentla nezinye ezinikezelwe ngumfundi mpandi ndiyaziqonda ngokupheleleyo.Yonke into ebendingayiqondi iphendulekile ngokwanelisayo .

Nceda utike ibokisi oumelana nayo

Ndiyavuma umntwana wam angafotwa

Andivumi ukba umntwana wam afotwe

Ityikitywe eRhodes University

Mthathi nxaxheba

Bhala igama Mfundi Mphandi	Tyikitya	Umhla

Bhala igama Igqina	Tyikitya	Umhla

Bhala igama	Tyikitya	Umhla

A.4. CONSENT ISSUES- PARTICIPANT

PARTICIPANT CONSENT

I,……………………………………………………………………, willingly give consent to allow,…………………………………………………………….…, to participate in the research project **"Soccer specific physical and technical characteristics of South African Youth Footballers".** I have been informed about the aim and purpose of the study as well as the possible risk factors and potential benefits. The primary researcher has explained all procedures, risks and benefits both verbally and in writing. Thus I am fully aware of what is expected in order to fully comply and participate in this research project.

By agreeing to partake in this study, I accept joint responsibility with the Department of Human Kinetics and Ergonomics should an injury occur. I waive any legal recourse against the researcher, or against Rhodes University, and will take full responsibility in the event that an injury occurs which is self-inflicted or through the act of non-compliance to researchers instructions. I understand that if I feel any discomfort, pain or ill health during the protocol I may stop and withdraw my consent at any time. I understand that my involvement in the team will not be comprised if I choose to withdraw from the current study.

I understand that my privacy will be maintained at all times and what specific information will be taken from the previously described protocol. I give full consent for my collected information to be used in the research project. I am aware that should photographs be taken, that firstly my consent is given and secondly that recognizable features will be blurred.

I have read and understood the information above as well as the additional information provided by the researcher. Any further queries have been answered to my satisfaction

Please tick the appropriate box

I agree to have my photo taken ☐

I do not agree to have my photo taken ☐

Signed at Rhodes University

PARTICIPANT

(Print name)	(Signed)	(Date)

RESEARCHER

(Print name)	(Signed)	(Date)

WITNESS

(Print name)	(Signed)	(Date)

A.5. CONSENT ISSUE- GUARDIAN

PARENTAL/GUARDIAN CONSENT

I,…………………………………………………………………………, willingly give consent to allow,………………………………………………………………..…, to participate in the research project **"Soccer specific physical and technical characteristics of South African Youth Footballers".** I have been informed about the aim and purpose of the study as well as the possible risk factors and potential benefits both verbally and in writing. Thus I am fully aware of what is expected in order for my child to comply and participate in this research project.

By agreeing to partake in this study, I accept joint responsibility with the Department of Human Kinetics and Ergonomics should an injury occur. I waive any legal recourse against the researcher, or against Rhodes University, and will take full responsibility in the event that an injury occurs which is self-inflicted or through act of non-compliance to researchers instructions. I understand that if my child feels any discomfort, pain or ill health during the protocol he may stop and withdraw consent at any time. I understand that my child's involvement in the team will not be influenced by not participating in the study.

I understand that my child's privacy will be maintained at all times and what specific information will be taken from the previously described protocol. I give full consent for my child's collected information to be used in the research project. I am aware that should photographs be taken, that firstly my consent is given and secondly that recognizable features will be blurred.

I have read and understood the information above as well as the additional information provided by the researcher. Any further queries have been answered to my satisfaction

Please tick the appropriate box

I agree to have my child's photo taken ☐

I do not agree to have my child's photo taken ☐

Signed at Rhodes University

PARTICIPANT

________________	________________	________________
(Print name)	(Signed)	(Date)

RESEARCHER

________________	________________	________________
(Print name)	(Signed)	(Date)

WITNESS

________________	________________	________________
(Print name)	(Signed)	(Date)

A.6. DEMOGRAPHIC, SOCIOECONOMIC AND FOOTBALLING HISTORY QUESTIONNAIRE

General

Name: ____

Age: _______________

Race: ______________________

Home Language: _______________

Home Town: _________________

Do you have medical aid or are involved in a medical assistance program?

____

Schooling

What grade are is you in?________________________________

If not at school, reason for leaving (too expensive, too far from home, started working etc)

____

What transport do you use to get to school(car, bus, walking etc)?

____

The Household

Who do you live with (Number of parents, brothers, sisters etc)?

____

____

Who supports the family financially? Is it more than one person?

____

____

How much does the family earn per month?

____

____

Soccer

What was the age did you start playing football?

____

How much experience do you have in terms of total years?

____

How many hours a week does you play football for?

____

How much of that is unstructured play, practice or a game?

____

A.7. DEMOGRAPHIC, SOCIOECONOMIC AND FOOTBALLING HISTORY QUESTIONNAIRE

ISIMO NGOKOKUHLALA NEZOQOQOSHO

GABALALA

Igama:______________________________

Iminyaka:___________________

Uhlanga:____________________

Ulwimi Lwasekhaya:____________

Isixeko:_______________________

Ingaba unayo incwadi ekuncedayo kweze mpilo okanye uyinxalenye ye nkqubo enceda ngokwe zempilo?____________________

Esikolweni

Wenza eliphi ibanga?______________

Ukuba awufundi uyekiswe yintoni (indleko zixhomile, ingaba sikude nekhaya, uqale ukusebenza njalo njalo)

____

Ingaba usebenzisa esiphi isithuthi xa usiya esikolweni (imoto, ibhasi, uhamba ngenyawo njalo njalo)

____

Ekhaya

Uhlala nabani (inani labazali, abantakwenu, nodade wenu njalo njalo)?

____

Ngubani Oxhasa usapho ngokwa sezimalini? Ingaba umnye okanye baninzi?

____

Ingaba usapho lurhola malini ngenyanga?

____

Ibhola

Ingaba uqale udlala uneminyaka emingaphi ibhola ekhatywayo?

____

Ingaba unamava eminyaka emingaphi xa iyonke?

____

Ingaba zingaphi iiyure ngeveki ozichithela kwibhola ekhatywayo?

____

Nidlala ixesha eli ngakanani ningaqeqeshwa, ningazilolongi okanye umdlalo?

____

APPENDIX B

B.1. LETTER FROM ETHICAL STANDARDS COMMITTEE

RHODES UNIVERSITY
Where leaders learn

Rhodes University Ethical Standards Committee
PO Box 94, Grahamstown, 6140, South Africa
t: +27 (0) 46 603 8055
f: +27 (0) 46 603 8822
e: ethics-committee@ru.ac.za

www.ru.ac.za/research/research/ethics

September 2017

Ashley De Beer
ashleycdebeer@gmail.com

Dear Ashley De Beer,

Re: HUMAN SUBJECTS ETHICS APPLICATION
Soccer specific physical and technical characteristics of South African Youth Footballers
Reference number: 8060198
Submitted: 6/20/2017

This letter confirms that the above research proposal has been reviewed by the Rhodes University Ethical Standards Committee (RUESC).

The committee decision is APPROVED pending receipt of gate keeper's permission.

Please ensure that the ethical standards committee is notified should any substantive change(s) be made, for whatever reason, during the research process. This includes changes in investigators. Please also ensure that a brief report is submitted to the ethics committee on completion of the research. The purpose of this report is to indicate whether the research was conducted successfully, if any aspects could not be completed, or if any problems arose that the ethical standards committee should be aware of. If a thesis or dissertation arising from this research is submitted to the library's electronic theses and dissertations (ETD) repository, please notify the committee of the date of submission and/or any reference or cataloguing number allocated.

Sincerely,

Helen Kruuse
Chair: Human Subjects Ethics sub-committee, RUESC

Note:
1. This clearance is valid for three years from the date of this letter.
2. The ethics committee cannot grant retrospective ethics clearance.
3. Progress reports should be submitted annually unless otherwise specified in the clearance letter.

B.2. ETHICAL CONSIDERATIONS

Human Kinetics and Ergonomics Ethical Clearance

RHODES UNIVERSITY
Where leaders learn

Protocol Number	HKE-2017-05											
Protocol Title	Soccer specific physical, cognitive and technical characteristics of South African Youth Footballers											
Level	Staff project			Student project		U		H		M	**X**	D
	Post Doc			Name	Ashley De Beer (g12D4857)							
Principal Investigator	Andrew Todd (phed009)			**RU Staff**	Yes	**X**	No					
Submission Date	2017-05-23											
Submission Type	Query		Primary		Full	X						
Reviewers	Miriam Mattison & Ben Ryan											
Sub-Committee Recommendation	**Approve**	**X**		**This is the majority recommendation**	X							
	Approve with stipulations											
	Disapprove											
	No ethics approval required											
	Refer to RUESC	**X**		**A minority registers dissent**								
Review comments	Approval from the Rhodes University Ethical Standards Committee is required due to research on minors.											

Further particulars for reporting to NHREC

This project involves *Level 2* Health Research *(drug research, biomedical research involving human tissues, high-budget & high technology research)*	Yes		No	X
This project is a *clinical trial*	Yes		No	X
This project involves *child participants*	Yes	X	No	
This project requires *ministerial consent*	Yes		No	X
This project involves *human* blood, tissues and genetic material	Yes		No	X
If yes:				
This is in accordance with provisions as per Government Gazette No.35099	Yes		No	
Or				
Biological material purchased from a commercial source	Yes		No	
This research has *environmental implications*	Yes		No	X

Confidential
HKE Ethical Committee Review Form

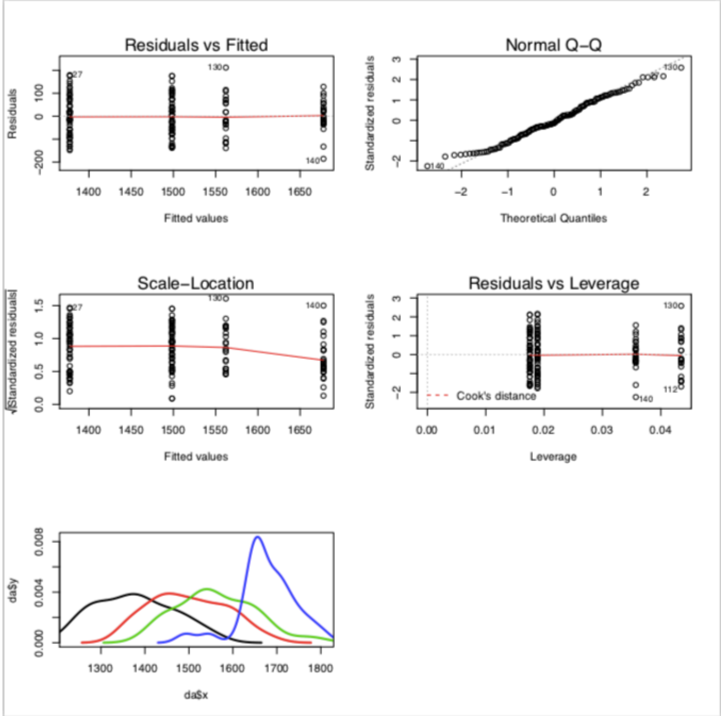
APPENDIX C

C.1. Tests of Normality, Homogeneity of Variance and Statistical analysis

C.1.Age

C.1.1. Stature

C.1.1.1. Test of Normality, Homogeneity of Variance and Statical analysis

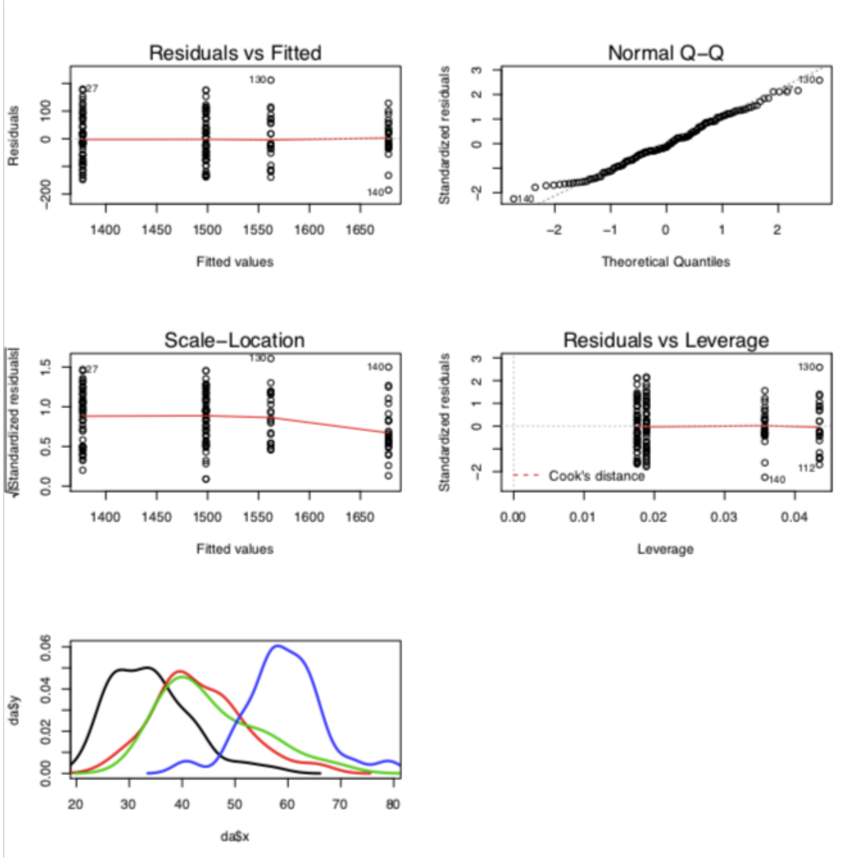


C.1.1.2. Post- hoc Turkey test of Stature for Age

```
Anova Table (Type III tests)

Response: H
              Sum Sq  Df   F value    Pr(>F)
(Intercept) 100544415   1 14263.779 < 2.2e-16 ***
AGE           1768754   3    83.642 < 2.2e-16 ***
Residuals     1106682 157
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> print(lsmeans(model,list(pairwise~AGE)), ADJUST = C("tukey"))
$`lsmeans of AGE`
 AGE   lsmean       SE  df lower.CL upper.CL
 A   1377.340 11.53251 157 1354.561 1400.119
 B   1498.333 11.12050 157 1476.368 1520.298
 C   1562.043 17.50644 157 1527.465 1596.622
 D   1677.571 15.86656 157 1646.232 1708.911

Confidence level used: 0.95

$`pairwise differences of contrast`
 contrast    estimate       SE  df t.ratio p.value
 A - B     -120.99371 16.02074 157  -7.552  <.0001
 A - C     -184.70386 20.96364 157  -8.811  <.0001
 A - D     -300.23181 19.61495 157 -15.306  <.0001
 B - C      -63.71014 20.73984 157  -3.072  0.0133
 B - D     -179.23810 19.37558 157  -9.251  <.0001
 C - D     -115.52795 23.62674 157  -4.890  <.0001

P value adjustment: tukey method for comparing a family of 4 estimates
```

C.1.2. Weight

C.1.2.1. Test of Normality, Homogeneity of Variance and Statical analysis

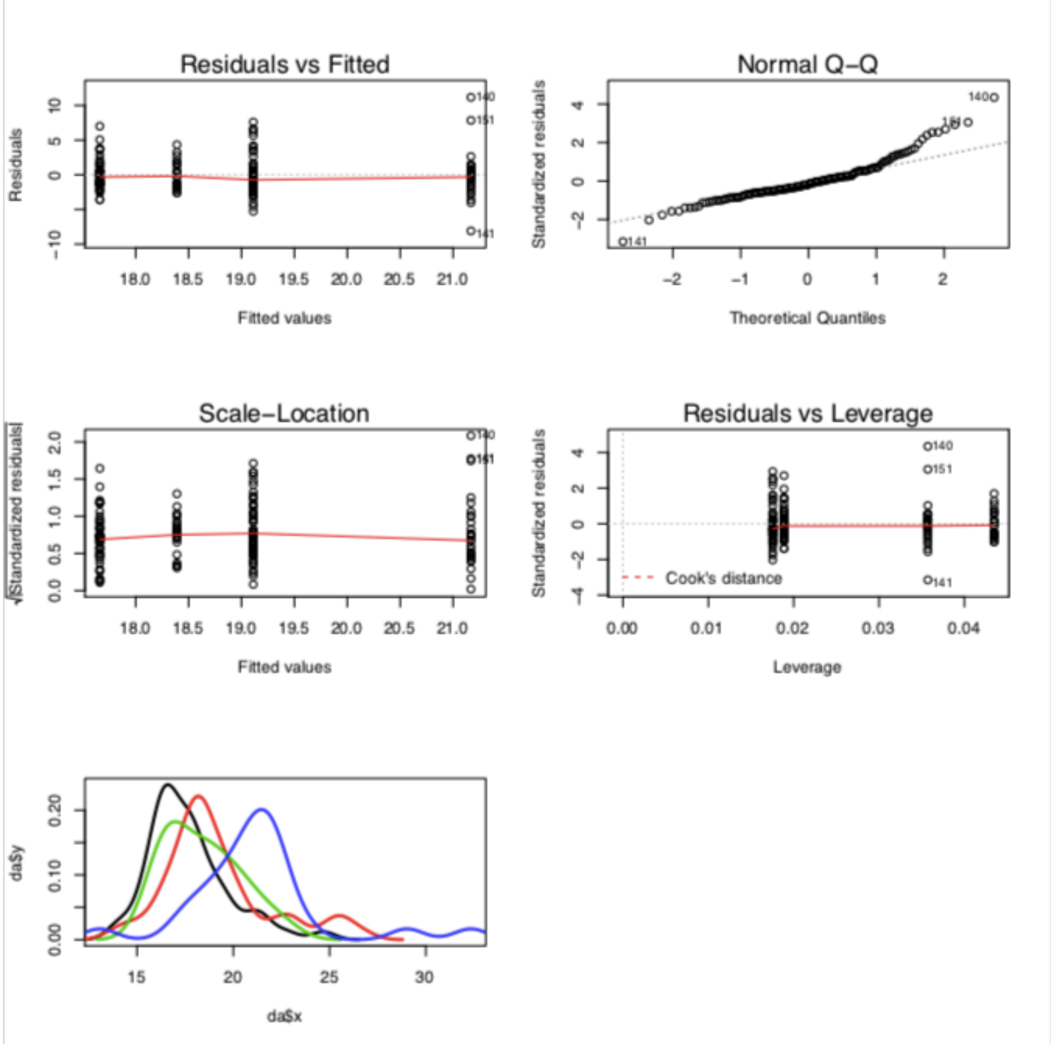


C.1.2.2. Post- hoc Turkey test of Weight for Age

```
    Pairwise comparisons using Wilcoxon rank sum test

data:  cs$W and cs$AGE

  A       B       C
B 8.8e-08 -       -
C 2.9e-06 0.46    -
D 6.2e-12 9.1e-10 4.8e-06

P value adjustment method: BH
```

C.1.3. Body Mass Index

C.1.3.1. Test of Normality, Homogeneity of Variance and Statical analysis

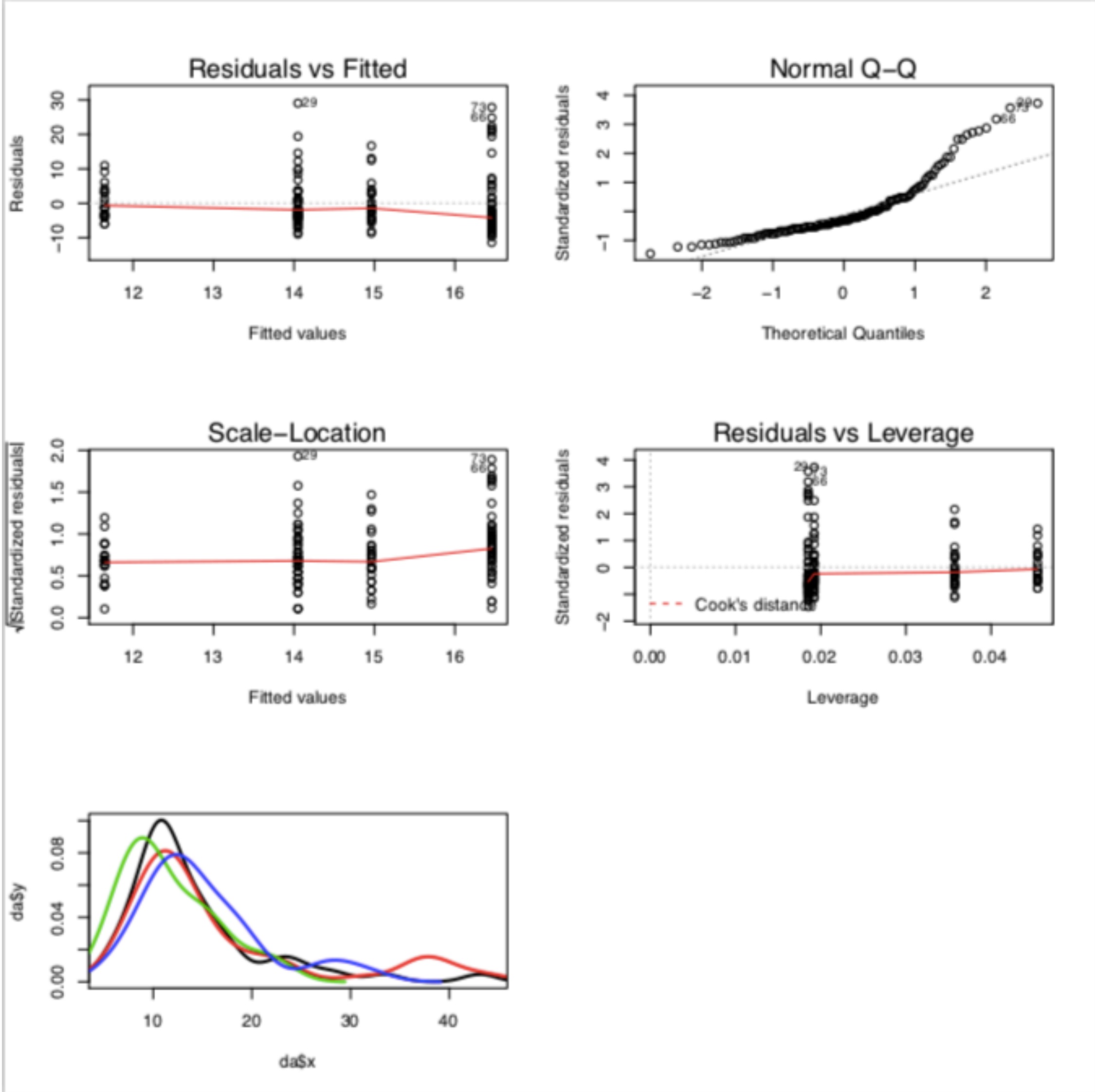


C.1.3.2. Post-hoc Turkey test of Body Mass Index on Age

```
    Pairwise comparisons using Wilcoxon rank sum test

data:  cs$BMI and cs$AGE

  A       B       C
B 0.00174 -       -
C 0.14892 0.34139 -
D 1.4e-06 0.00135 0.00052

P value adjustment method: BH
```

C.1.4. Total Fat

C.1.4.1. Test of Normality, Homogeneity of Variance and Statical analysis

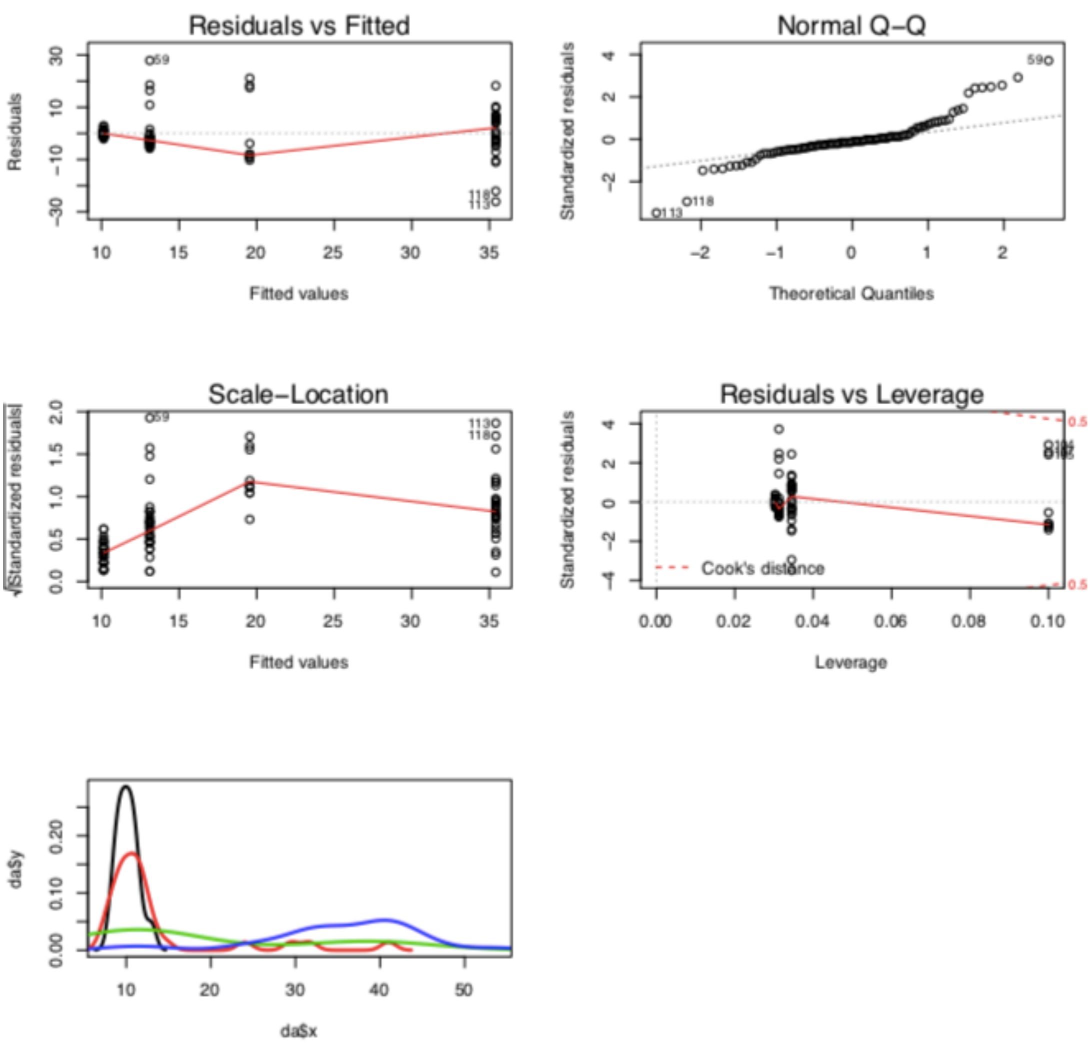


C.1.4.2. Post-hoc Turkey test of Total Fat on Age

```
    Pairwise comparisons using Wilcoxon rank sum test

data:  cs$TF and cs$AGE

  A    B    C
B 0.45 -    -
C 0.30 0.12 -
D 0.35 0.75 0.12

P value adjustment method: BH
```

C.1.5. Power

C.1.5.1. Test of Normality, Homogeneity of Variance and Statical analysis

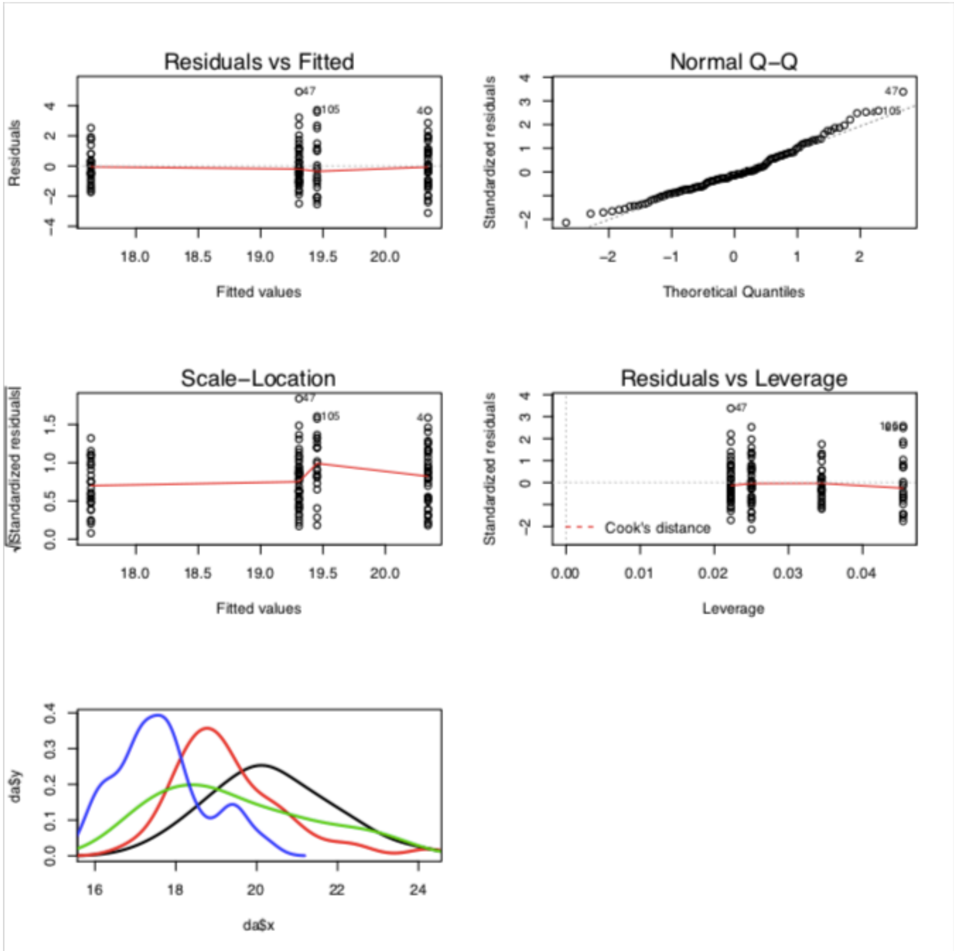


C.1.5.2. Post-hoc Turkey test of Power on Age

```
    Pairwise comparisons using Wilcoxon rank sum test

data:  cs$VJ and cs$AGE

  A       B       C
B 0.1138  -       -
C 0.0073  0.1138  -
D 8.6e-10 1.2e-08 0.0073

P value adjustment method: BH
```

C.1.6. Agility

C.1.6.1. Test of Normality, Homogeneity of Variance and Statical analysis

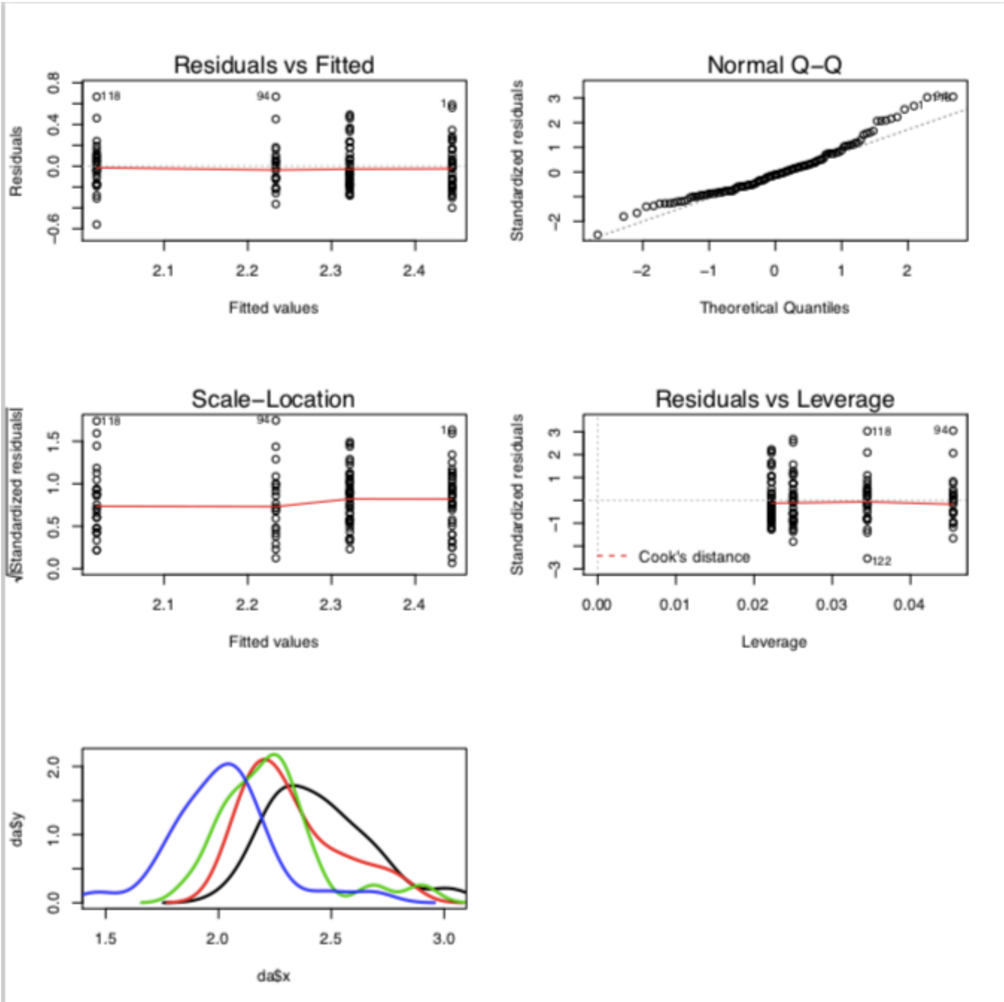


C.1.6.2. Post-hoc Turkey test of Agility on Age

```
    Pairwise comparisons using Wilcoxon rank sum test

data:  cs$AG and cs$AGE

  A       B       C
B 0.00114 -       -
C 0.05671 1.00000 -
D 1.2e-08 3.5e-06 0.00053

P value adjustment method: BH
```

C.1.7. Acceleration

C.1.7.1. Test of Normality, Homogeneity of Variance and Statical analysis

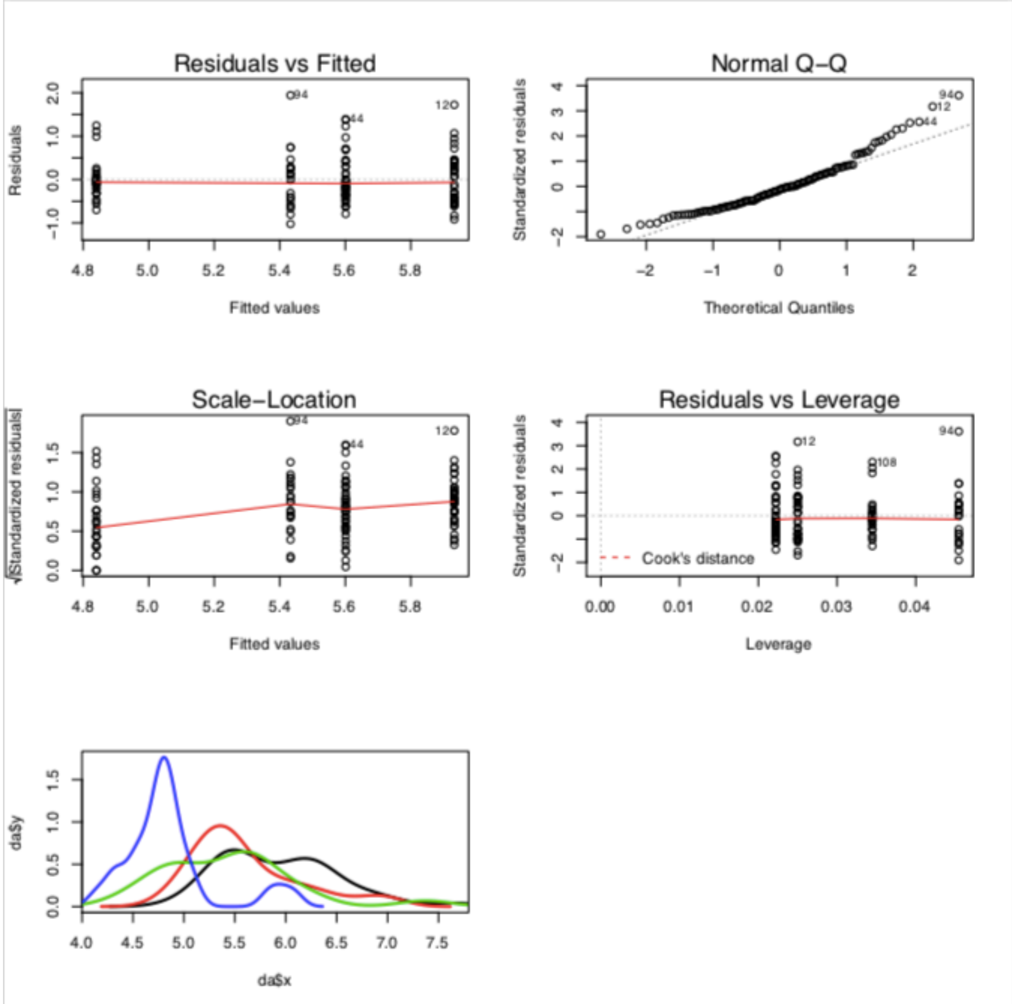


C.1.7.2. Post-hoc Turkey test of Acceleration on Age

```
    Pairwise comparisons using Wilcoxon rank sum test

data:  cs$AC and cs$AGE

  A       B       C
B 0.00781 -       -
C 0.00057 0.10615 -
D 1.1e-08 2.7e-07 0.00099

P value adjustment method: BH
```

C.1.8. Speed

C.1.8.1. Test of Normality, Homogeneity of Variance and Statical analysis

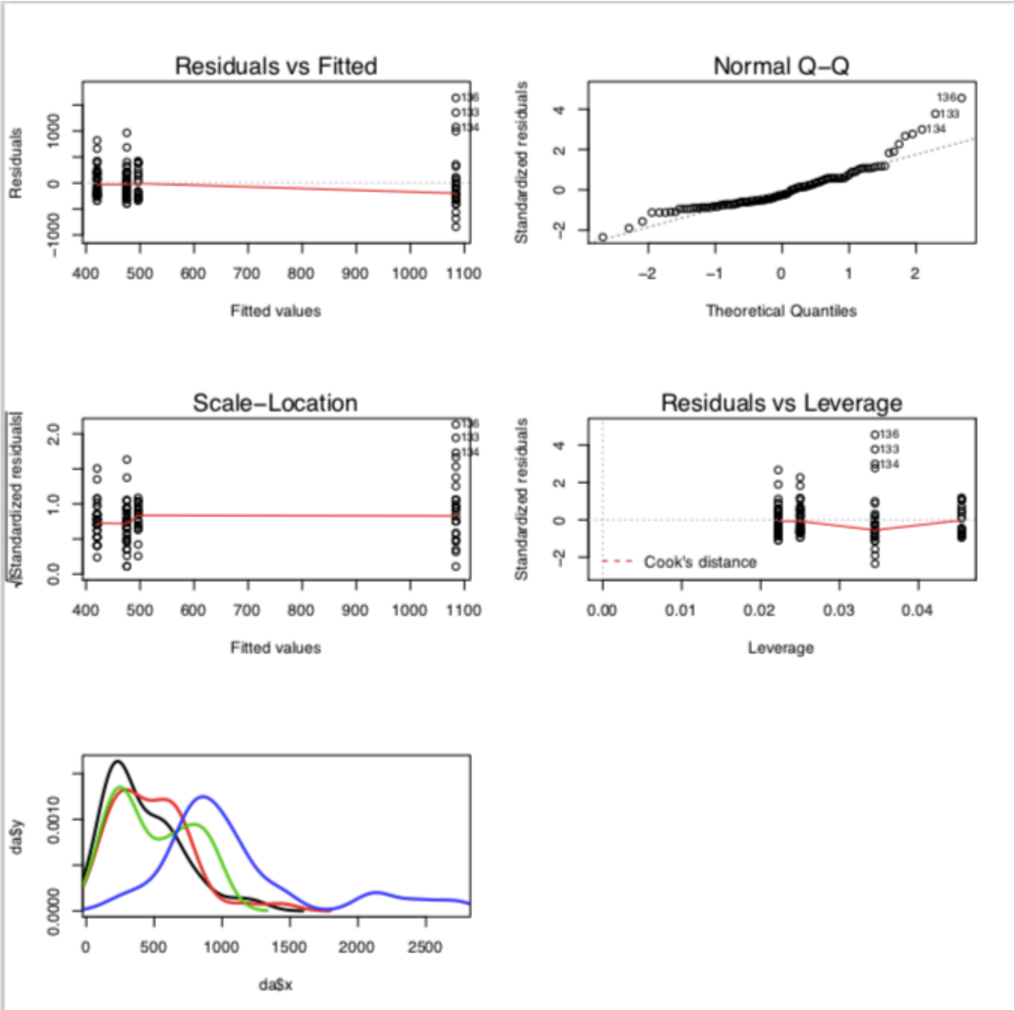


C.1.8.2. Post-hoc Turkey test of Speed on Age

```
    Pairwise comparisons using Wilcoxon rank sum test

data:  cs$SP and cs$AGE

  A       B       C
B 0.00438 -       -
C 0.00651 0.32315 -
D 2.4e-09 1.7e-08 0.00084

P value adjustment method: BH
```

C.1.9. Endurance

C.1.9.1. Test of Normality, Homogeneity of Variance and Statical analysis



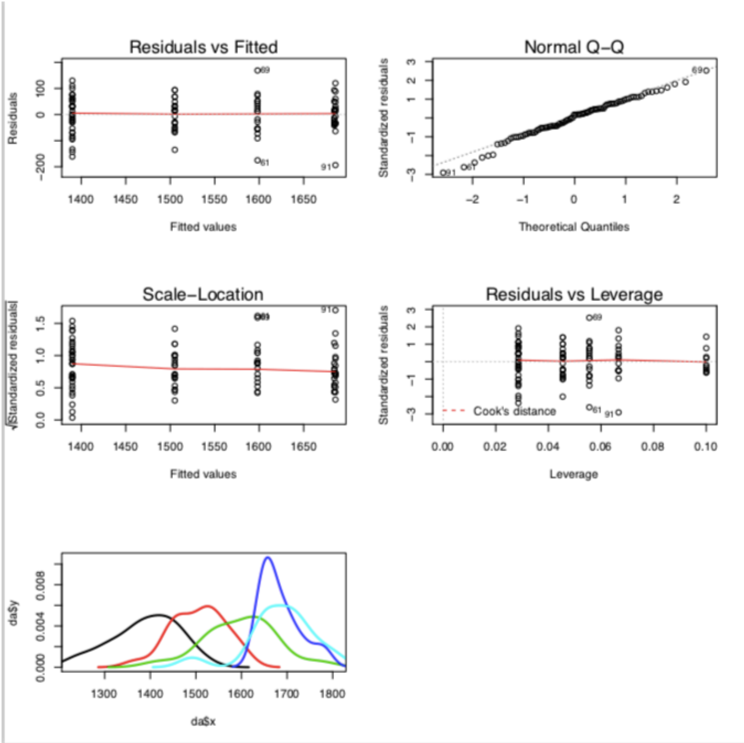
C.1.9.2. Post-hoc Turkey test of Endurance on Age

```
    Pairwise comparisons using Wilcoxon rank sum test

data:  cs$YO and cs$AGE

  A       B       C      
B 0.31    -       -      
C 0.31    0.67    -      
D 8.9e-08 8.9e-08 4.8e-05

P value adjustment method: BH
```

C.2.Maturity

C.2.1. Stature

C.2.1.1. Test of Normality, Homogeneity of Variance and Statical analysis

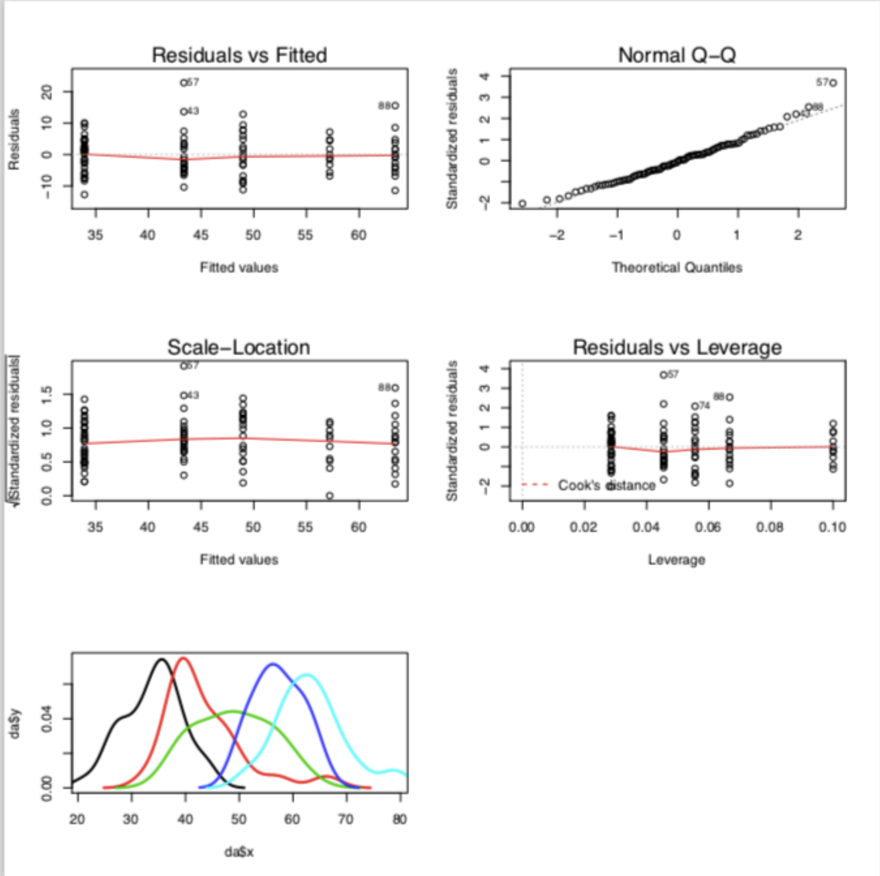


C.2.1.2. Post- hoc Turkey test of Stature for Maturity

```
> print(lsmeans(model,list(pairwise~GR)), ADJUST = C("tukey"))
$`lsmeans of GR`
 GR   lsmean       SE df lower.CL upper.CL
 A  1389.914 11.64803 95 1366.790 1413.039
 B  1505.136 14.69181 95 1475.969 1534.303
 C  1598.111 16.24240 95 1565.866 1630.356
 D  1684.400 21.79147 95 1641.138 1727.662
 E  1685.667 17.79266 95 1650.344 1720.990

Confidence level used: 0.95

$`pairwise differences of contrast`
 contrast    estimate       SE df t.ratio p.value
 A - B    -115.222078 18.74902 95  -6.145  <.0001
 A - C    -208.196825 19.98730 95 -10.416  <.0001
 A - D    -294.485714 24.70921 95 -11.918  <.0001
 A - E    -295.752381 21.26630 95 -13.907  <.0001
 B - C     -92.974747 21.90125 95  -4.245  0.0005
 B - D    -179.263636 26.28150 95  -6.821  <.0001
 B - E    -180.530303 23.07440 95  -7.824  <.0001
 C - D     -86.288889 27.17874 95  -3.175  0.0169
 C - E     -87.555556 24.09138 95  -3.634  0.0040
 D - E      -1.266667 28.13267 95  -0.045  1.0000

P value adjustment: tukey method for comparing a family of 5 estimates
```

C.2.2. Weight

C.2.2.1. Test of Normality, Homogeneity of Variance and Statical analysis

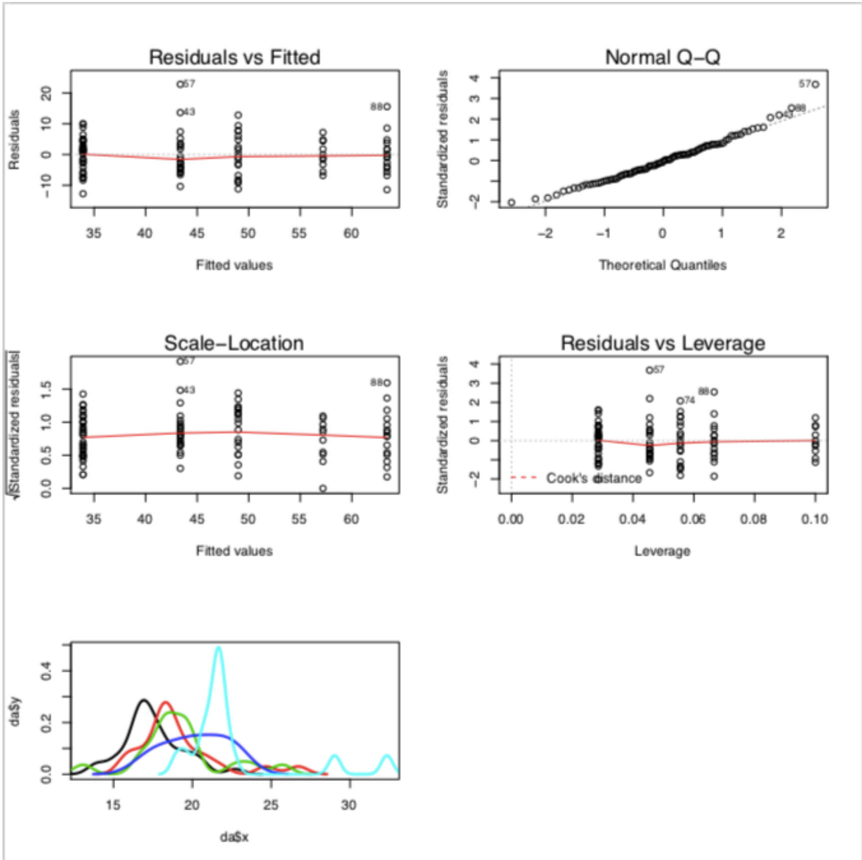


C.2.2.2. Post- hoc Turkey test of Weight for Maturity

```
$`lsmeans of GR`
 GR    lsmean       SE df lower.CL upper.CL
 A   33.92571 1.073414 95 31.79472 36.05671
 B   43.36364 1.353911 95 40.67578 46.05149
 C   48.97778 1.496805 95 46.00624 51.94931
 D   57.20000 2.008174 95 53.21327 61.18673
 E   63.41333 1.639668 95 60.15818 66.66848

Confidence level used: 0.95

$`pairwise differences of contrast`
 contrast    estimate       SE df t.ratio p.value
 A - B      -9.437922 1.727800 95  -5.462  <.0001
 A - C     -15.052063 1.841913 95  -8.172  <.0001
 A - D     -23.274286 2.277056 95 -10.221  <.0001
 A - E     -29.487619 1.959778 95 -15.046  <.0001
 B - C      -5.614141 2.018291 95  -2.782  0.0499
 B - D     -13.836364 2.421949 95  -5.713  <.0001
 B - E     -20.049697 2.126402 95  -9.429  <.0001
 C - D      -8.222222 2.504634 95  -3.283  0.0122
 C - E     -14.435556 2.220120 95  -6.502  <.0001
 D - E      -6.213333 2.592542 95  -2.397  0.1252

P value adjustment: tukey method for comparing a family of 5 estimates
```

C.2.3. Body Mass Index

C.2.3.1. Test of Normality, Homogeneity of Variance and Statical analysis

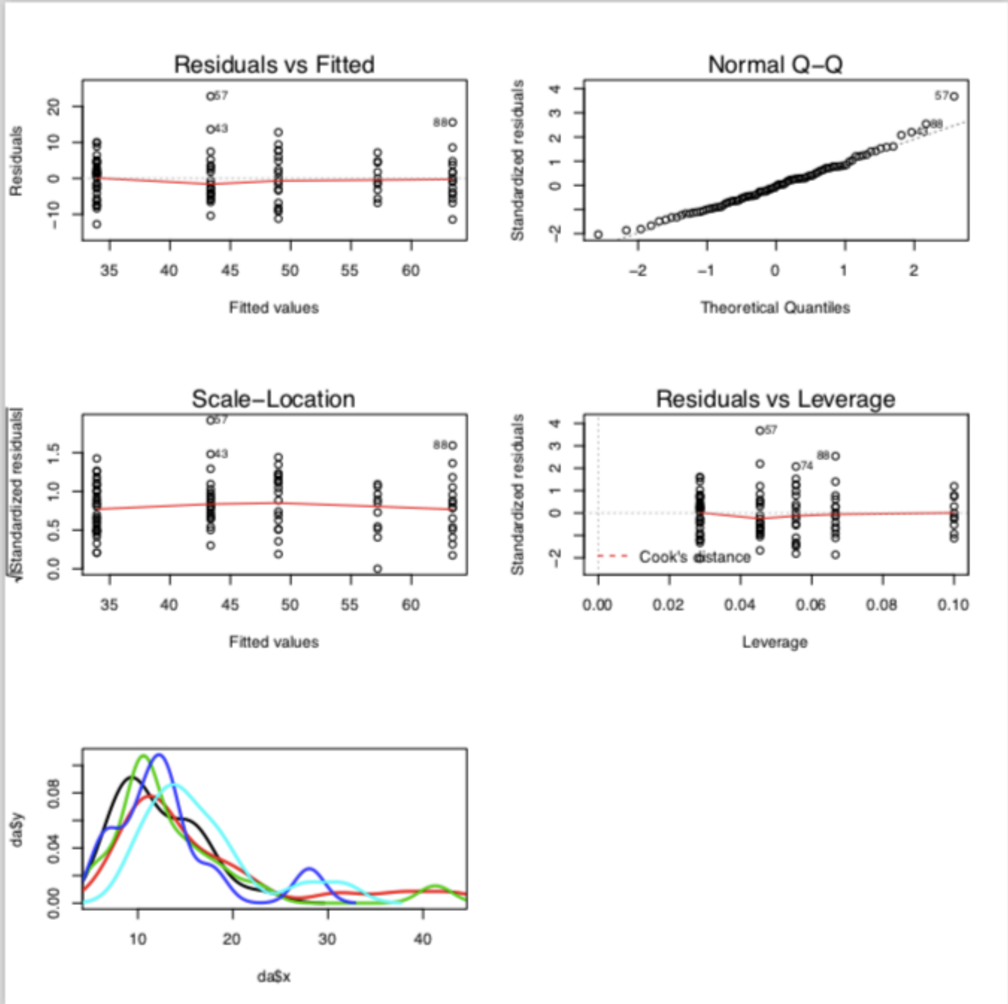


C.2.3.2. Post- hoc Turkey test of Body Mass Index for Maturity

```
    Pairwise comparisons using Wilcoxon rank sum test

data:  cs$BMI and cs$GR

  A       B      C      D
B 0.0168  -      -      -
C 0.0115  0.6054 -      -
D 0.0025  0.1307 0.3180 -
E 3.8e-06 0.0012 0.0025 0.1798

P value adjustment method: BH
```

C.2.4. Total Fat

C.2.4.1. Test of Normality, Homogeneity of Variance and Statical analysis

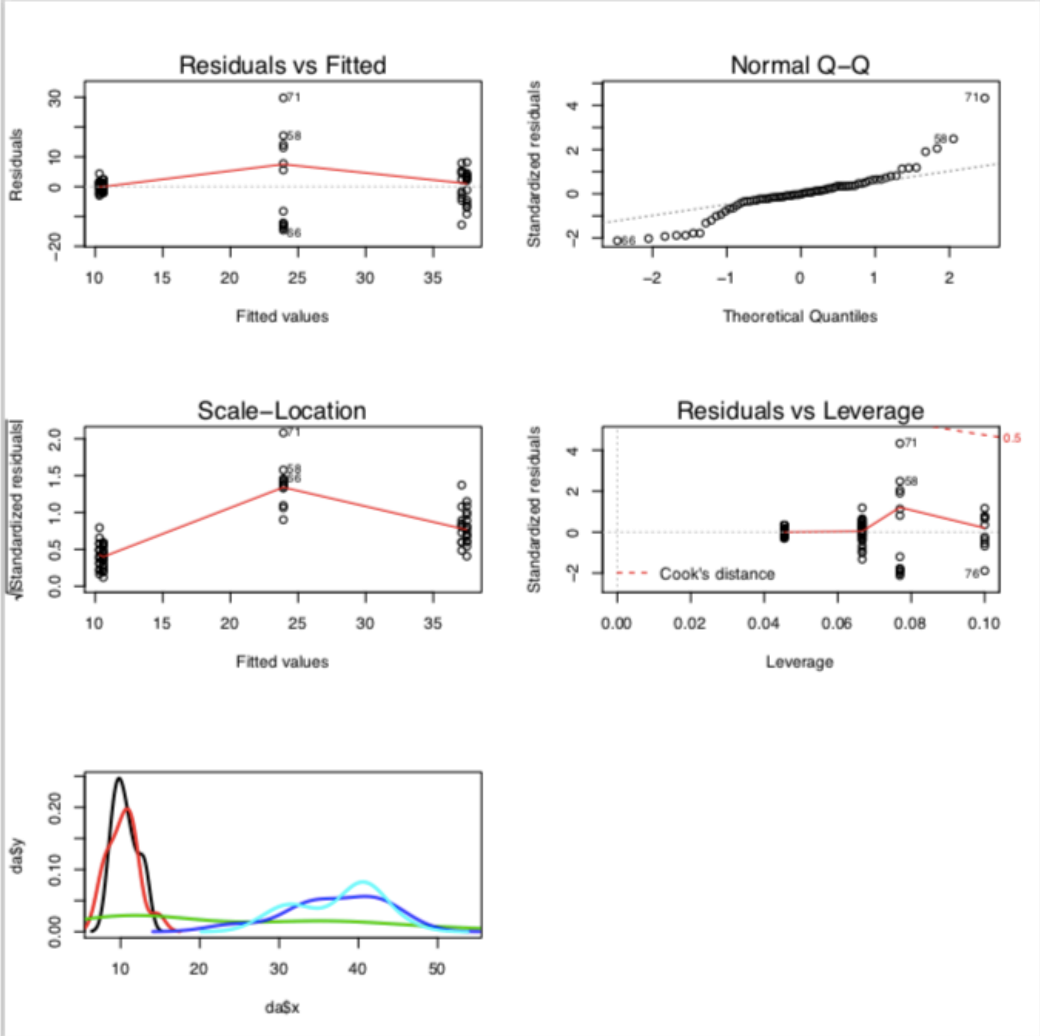


C.2.4.2. Post- hoc Turkey test of Total Fat for Maturity

```
    Pairwise comparisons using Wilcoxon rank sum test

data:  cs$TF and cs$GR

  A    B    C    D
B 0.22 -    -    -
C 0.68 0.55 -    -
D 0.87 0.55 1.00 -
E 0.11 0.55 0.22 0.22

P value adjustment method: BH
```

C.2.5. Power

C.2.5.1. Test of Normality, Homogeneity of Variance and Statical analysis

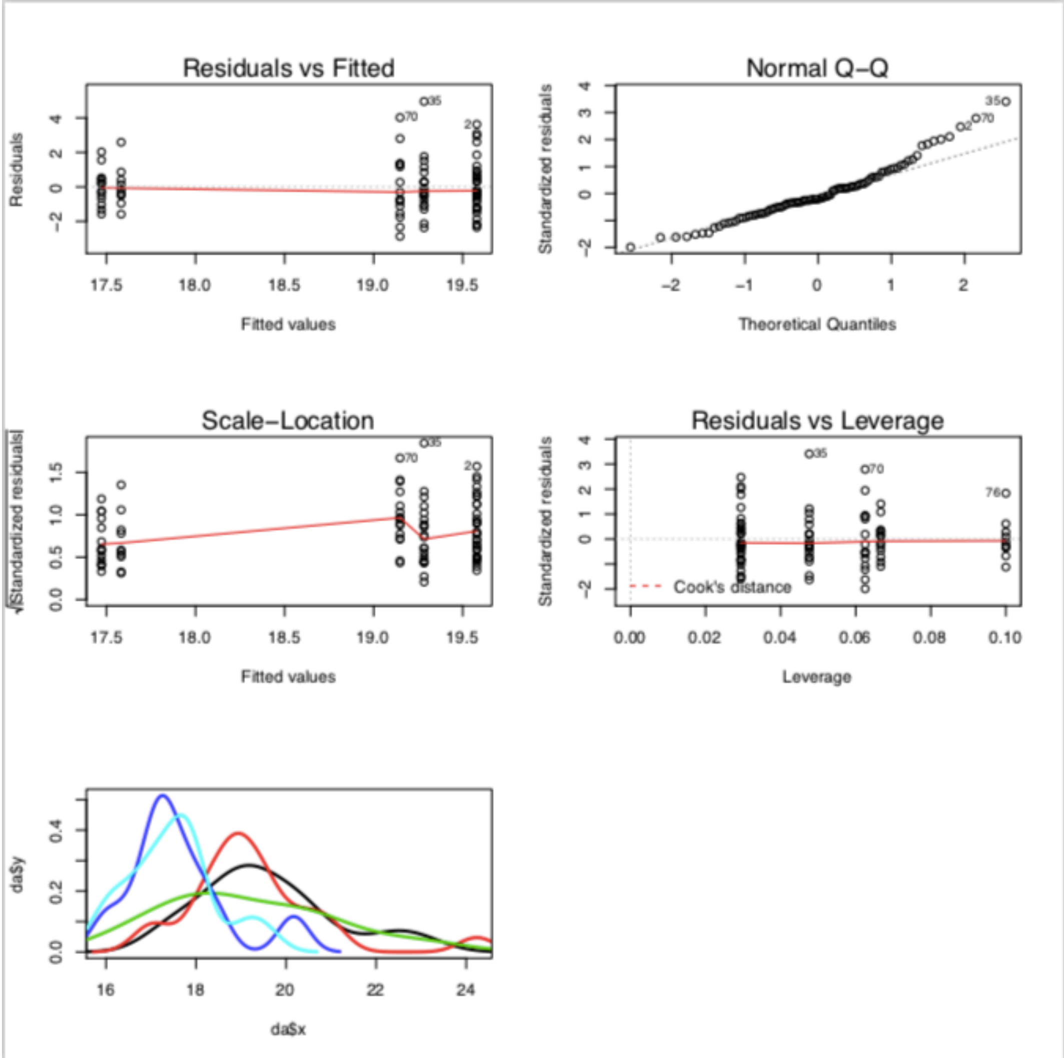


C.2.5.2. Post- hoc Turkey test of Power for Maturity

```
    Pairwise comparisons using Wilcoxon rank sum test

data:  cs$VJ and cs$GR

  A       B       C      D
B 0.7381  -       -      -
C 0.0073  0.0094  -      -
D 2.7e-05 8.9e-05 0.0295 -
E 3.5e-06 1.7e-05 0.0172 0.8242

P value adjustment method: BH
```

C.2.6. Agility

C.2.6.1. Test of Normality, Homogeneity of Variance and Statical analysis

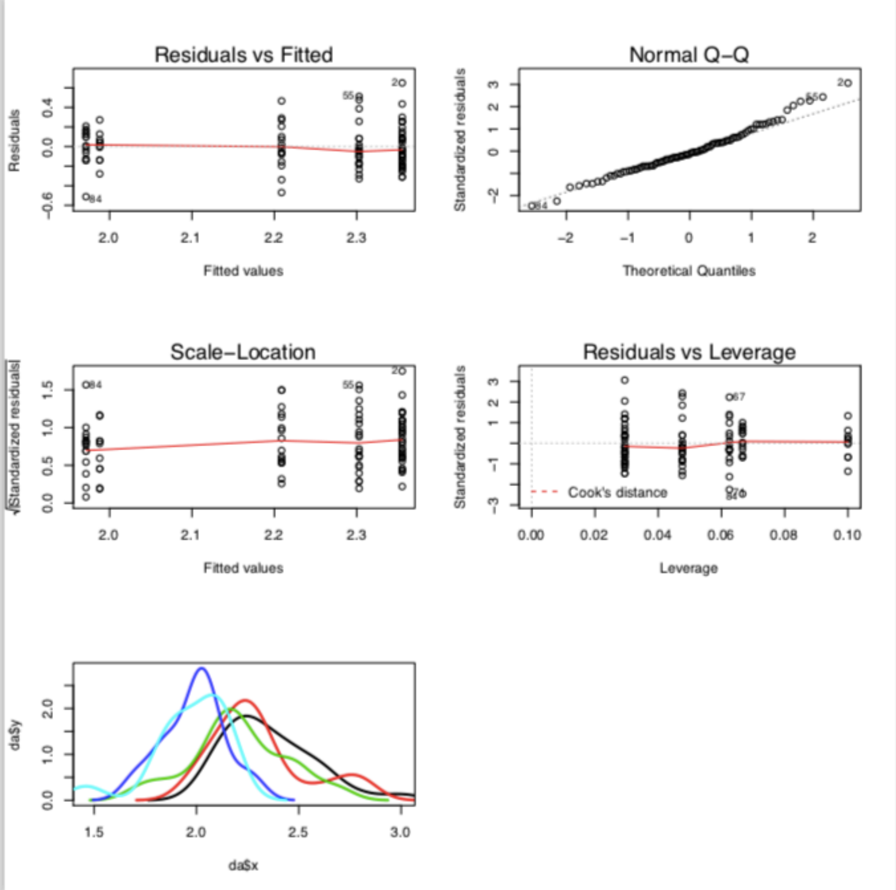


C.2.6.2. Post- hoc Turkey test of Agility for Maturity

```
    Pairwise comparisons using Wilcoxon rank sum test

data:  cs$AG and cs$GR

  A       B       C       D
B 0.51920 -       -       -
C 0.51920 0.78331 -       -
D 0.00139 0.00331 0.03300 -
E 0.00014 0.00105 0.01105 0.97830

P value adjustment method: BH
```

C.2.7. Acceleration

C.2.7.1. Test of Normality, Homogeneity of Variance and Statical analysis

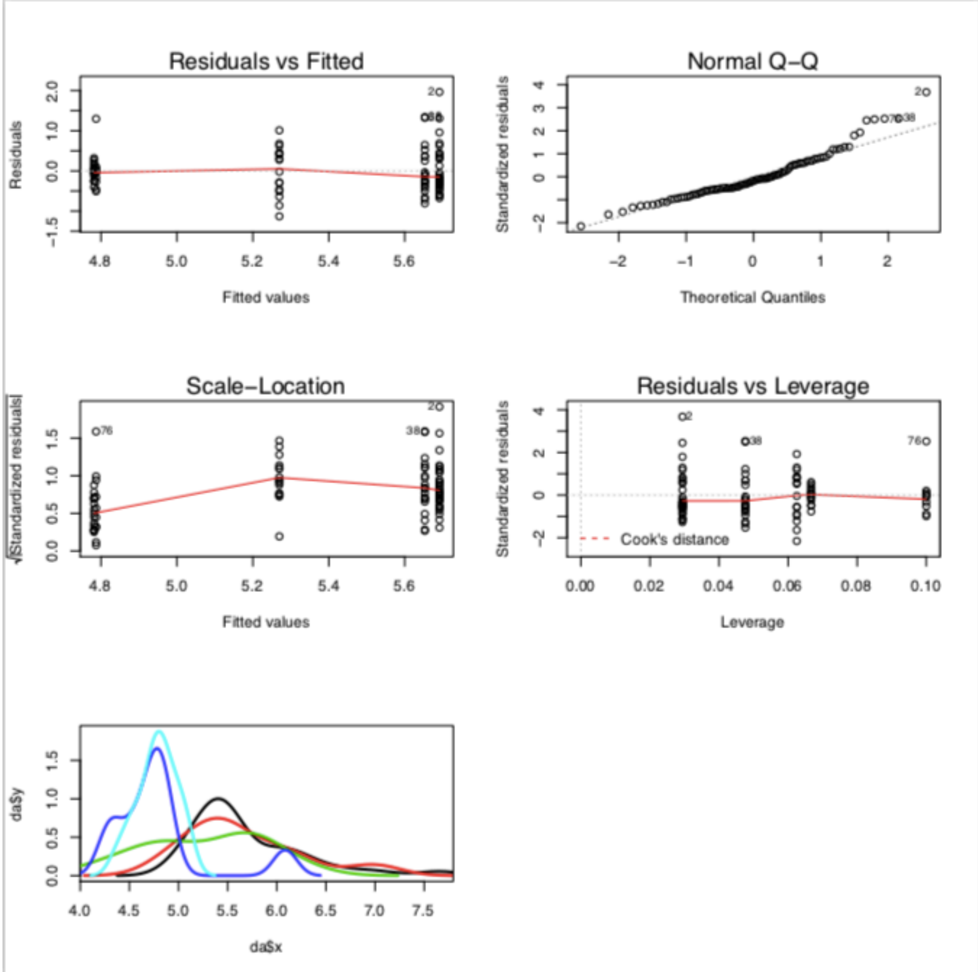


C.2.7.2. Post- hoc Turkey test of Acceleration for Maturity

```
$`lsmeans of GR`
 GR    lsmean         SE df lower.CL upper.CL
 A   2.355147 0.03693804 91 2.281774 2.428520
 B   2.302857 0.04700062 91 2.209496 2.396218
 C   2.208750 0.05384598 91 2.101792 2.315708
 D   1.988000 0.06811038 91 1.852707 2.123293
 E   1.971333 0.05561189 91 1.860867 2.081800

Confidence level used: 0.95

$`pairwise differences of contrast`
 contrast   estimate         SE df t.ratio p.value
 A - B    0.05228992 0.05977857 91   0.875  0.9055
 A - C    0.14639706 0.06529784 91   2.242  0.1739
 A - D    0.36714706 0.07748188 91   4.738  0.0001
 A - E    0.38381373 0.06676152 91   5.749  <.0001
 B - C    0.09410714 0.07147341 91   1.317  0.6816
 B - D    0.31485714 0.08275314 91   3.805  0.0023
 B - E    0.33152381 0.07281305 91   4.553  0.0002
 C - D    0.22075000 0.08682403 91   2.542  0.0903
 C - E    0.23741667 0.07740847 91   3.067  0.0232
 D - E    0.01666667 0.08793012 91   0.190  0.9997

P value adjustment: tukey method for comparing a family of 5 estimates
```

C.2.8. Speed

C.2.8.1. Test of Normality, Homogeneity of Variance and Statical analysis

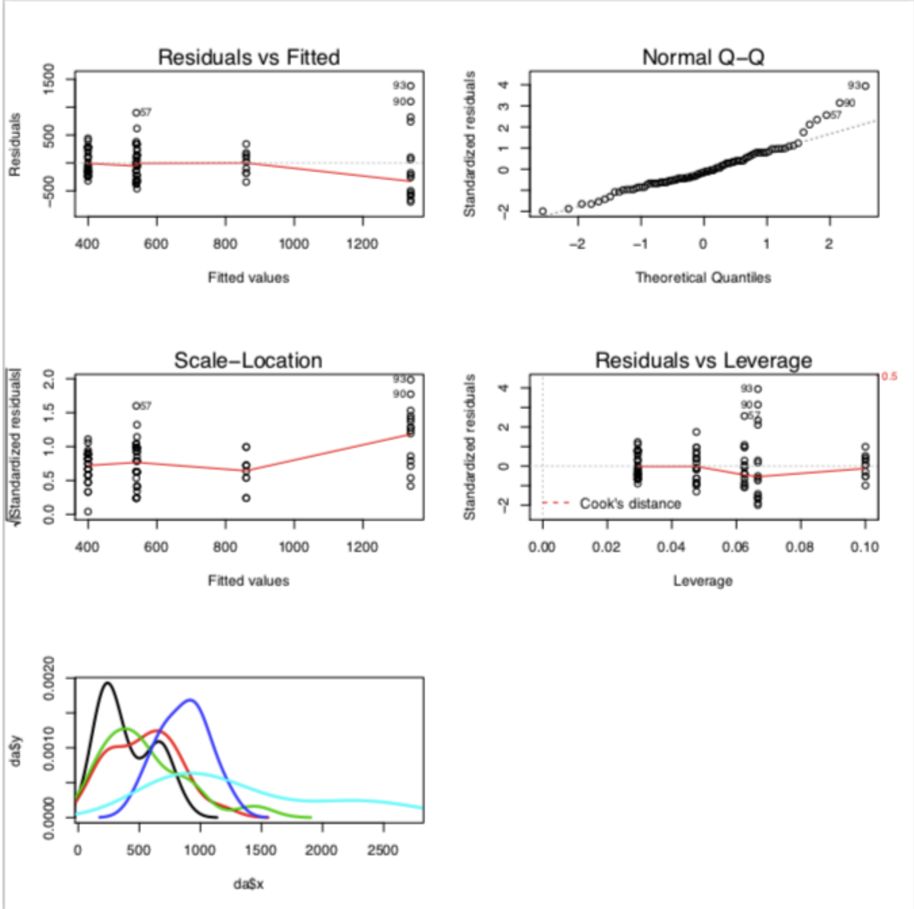


C.2.8.2. Post- hoc Turkey test of Speed for Maturity

```
    Pairwise comparisons using Wilcoxon rank sum test

data:  cs$SP and cs$GR

  A       B       C       D
B 0.78829 -       -       -
C 0.15286 0.19467 -       -
D 0.00017 0.00017 0.07785 -
E 4.9e-07 1.2e-05 0.05099 0.39965

P value adjustment method: BH
```

C.2.9. Endurance

C.2.9.1. Test of Normality, Homogeneity of Variance and Statical analysis



C.2.9.2. Post- hoc Turkey test of Endurance for Maturity

```
    Pairwise comparisons using Wilcoxon rank sum test

data:  cs$YO and cs$GR

  A       B       C       D
B 0.09678 -       -       -
C 0.21742 0.77031 -       -
D 0.00022 0.00724 0.01261 -
E 3.4e-06 0.00026 0.00086 0.12646

P value adjustment method: BH
```