A case study of the physical fitness testing battery within a Scottish Premier League Football Club's Academy

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Abstract

The advancement of fitness testing methods has assisted youth soccer coaches and practitioners with both talent identification and talent development. When implementing a testing battery for assessing physical fitness, consideration must be made to ensure that chosen tests are accurate, reliable, and provide value to key stakeholders within the talent development environment. Therefore, this study aimed to examine the physical fitness testing practices of a professional Scottish football academy via a mixed-methods case study approach. In total, fifty-nine male youth soccer players and six key stakeholders volunteered to participate. Players were assessed using five fitness measures used as part of the routine testing and monitoring battery at the club on three separate occasions across the season. Additionally, two focus groups were conducted involving key stakeholders within the academy coaching, and performance team, respectively, to investigate the rationale for, and perceptions of, the fitness testing battery. Results demonstrate a wide range of reliability scores (ICC= 0.32 – 0.98) for the fitness tests across the various age groups within the academy. The testing battery was able to discriminate between chronological age group and maturity status on some, but not all, occasions. Thematic analyses identified that building capacities within fundamental movement patterns, developing anaerobic qualities, and being mentally robust to overcome physical adversity were valued by stakeholders at the club. Testing was also seen as a benchmark or guide for coaches. However, the communication of these data could be simplified and more closely linked to technical aspects. This study identifies considerations for reliability, validity, and sensitivity of fitness tests used at the club's academy along with identifying priorities and areas for improvement of the testing battery within the talent development environment.

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List of Abbreviations

FIFA: fédération internationale de football association

TI: talent identification

TD: talent development

UEFA: union of european football association

COD: change of direction

SJ: squat jump

CMJ: countermovement jump

YYIRT1: Yo-Yo Intermittent Recovery Test Level 1

PHV: peak height velocity

ICC: intraclass correlation

CV: coefficient of variation

SD: standard deviation

ES: effect size

SWC: smallest worthwhile change

MDC: minimal detectable change

SEM: standard error of measurement

PAH%: predicted percentage of adult stature

FCM: football association's four corner model

SFA: scottish football association

DJ: drop jump

RSI: reactive strength index

MSS: maximal sprinting speed

GPS: global positioning system

ANOVA: one-way analysis of variance

Introduction

Soccer is considered the most popular sport worldwide. The Fédération Internationale de Football Association (FIFA) Big Count initiative (2006) stated that globally, around 270 million were regularly participating in soccer, more than any other sport. Although data in relation to this initiative has not been reported since, it is anticipated by many that this number will have grown over the last seventeen years considering the growth of facilities from grass roots to professional level, and formal engagement strategies to make football truly global through the governing bodies vision 2020-2023 (FIFA, 2020). The market size of the professional European soccer market has also had a dramatic increase across a similar timespan, documenting an increase in yearly revenue from €16.9 Billion in 2010/11 to €29.5 Billion in 2021/22 (Statista, 2023a). Together, these developments have had a major impact in talent identification (TI) and talent development (TD) within football club academies. The homegrown rule set out by the Union of European Football Association (UEFA) states that football clubs must include a minimum of eight homegrown players in their 25-player squad within European competitions. This means that these players must have been trained by their club or another club in the same national association for at least 3 years between the ages of 15 and 21 (UEFA, 2019). Developing talented young players and home-grown idols has benefited smaller clubs around the world who are able to command enormous life changing transfer fees from the top football clubs in Europe. More recently, countries like Saudi Arabia are spending more money than ever before in the transfer market with a record €7.6 billion being spent in the summer 2023 (Statista, 2023b). Soccer clubs can, therefore, benefit significantly from buying or selling young talent by implementing appropriate and efficient TD procedures. Consequently, TI and TD is, now more than ever, an essential component of any professional football club's strategy.

The TI and TD of youth players within youth soccer academies typically involves the input of key stakeholders such as coaches, scouts, sports scientists, and administrators. The conception of TI and TD is not an easy task, as definitions differ within the literature. Talent is generally associated with the belief of a player's precondition for success and with the result of the developmental process (Helsen et al., 2005). Thus, TI may refer to recognising and/or selecting player's participating in soccer who have the potential to progress into an elite player (Williams & Reilly, 2000). Meanwhile, TD describes when players are provided with an appropriate environment consisting of a high-performance development framework which combines support, coaching, training, and match-play in a systematic fashion designed to assist players reaching their potential (Vaeyens et al., 2009). Due to the multifaceted characteristics of performance in soccer and the complexity of the development process from youth player to first team level, a multi-dimensional spectrum of potentially relevant prognostic factors is a necessary consideration to understand the intricacy of these predictors. The development of a heuristic model for the classification of talent prediction highlighted potential factors including physical, psychological, physiological, and sociological characteristics (Williams & Reilly, 2000). Most quantitative methods for identifying talent are associated with universal conception of attributes for team sports athletes such as endurance, speed, strength, and agility (Wilson et al., 2016), which highlights the evolvement of physiological demands in soccer over recent years, particularly the demand on aerobic characteristics. Therefore, considerable emphasis is being placed on the physiological development of players to ensure they can meet these demands and subsequently playing a key role in TI and TD.

Many soccer clubs have developed their own TI and TD philosophies, methods, and processes that they implement to identify and develop young players. It is probable that the use of different testing measurements and lack of standardised protocol for the extraction of predictors can also influence their prognostic value (Murr, Raabe & Höner, 2018). The rationale for selection of specific testing measurements and their value to inform practitioners is often overlooked, yet is crucial to understand. Therefore, a better understanding of the rationale and perceptions of these methods and processes within the key stakeholders at the club would help with multidisciplinary collaboration.

General aim of thesis

Accordingly, the general aim of this thesis is to better understand the accuracy and discriminatory ability of a fitness testing battery in a professional club's academy along with gaining a better understanding of the perceptions and rationale of the testing battery within a multidisciplinary coaching team.

Literature Review

As discussed in the previous chapter, TI and TD of youth soccer players is a fundamental element within soccer academies. Due to the increased physical demands and progression in modern-day soccer, greater attention has been given to the physical and anthropometric attributes of youth players in the selection/deselection process (Williams, Ford & Drust; 2020). Thus, it is critical that the procedures and testing batteries in place that assist with the decision-making process of players within soccer academies provide reliable and valuable insight for coaches and practitioners to provide age- and stage-specific training programmes. This literature review aims to present and critically evaluate research on the use of physical fitness testing within soccer as well as exploring the impact of key stakeholder philosophy on TI and TD processes in youth soccer. To accomplish this, a search of academic literature was performed through databases such as PubMed and Web of Science. Key terms included “physical testing”, “fitness testing”, “performance testing”, “youth soccer”, “youth athlete”, “talent identification”, “coaching”, “stakeholder”, “perceptions”, “talent development”, “soccer”, and “football”. Additionally, research was gathered through reference lists of associated research articles.

Physical and Physiological Qualities in Soccer

Soccer players are expected to have exceptional tactical knowledge (Garganta, 2009), a multitude of psychological traits (Höner & Feichtinger, 2016), outstanding technical skill (Keller et al., 2016) and possess an array of physical abilities in order to succeed. Soccer is a high-intensity, intermittent sport requiring a wide range of physical attributes to achieve competitive success (Stolen et al., 2005). These multifaceted, intermittent bouts of activity include change of direction (COD), jumping, tackling, sprinting, and technical skill-based actions over a 90-minute game in a dynamic and ever-changing environment (Saramento et al., 2014). The efficiency of this collection of activities requires a complex interaction of physiological demands utilising both aerobic and anaerobic energy systems (Dolci et al., 2018). Recognition of the physical demands of training and match play is crucial to sufficiently analyse, monitor and define physical characteristics attributed to successful performance in soccer. Similar to senior soccer, youth players are expected to have sufficient physical qualities which are required to carry out the array of activities that occur during match-play (Le Gall et al., 2010). Currently, players' physical demands are higher than ever due to covering greater distances, reaching greater maximum velocities, and performing a higher number of sprints. Across 7 seasons of English Premier League soccer, high intensity running distance and actions increased by ~30% and ~50%, respectively (Barnes et al., 2014). More recently, across 5 seasons, small to moderate increases were observed in team running load for total distance, high intensity distance, and sprint distance (Allen et al., 2023). Consequently, the increased demands of senior soccer has the potential to have a significant influence in selection/deselection decisions and training prescription at youth level. Youth soccer also mirrors senior soccer with various competitive levels, which illustrates academies associated with professional soccer clubs being the highest competitive standard. With numerous clubs aiming to progress academy players to senior ranks, research involving these groups of players holds significance. By carrying out research within performance academies, football clubs may establish extensive information and understanding of the best practices and methods for producing and progressing the most talented players from within. Therefore, the overarching aim of youth soccer within professional academies is typically considered to be to prepare players towards a transition to senior training and competition.

Physical performance characteristics have been described to have a considerable influence on successful transition through academy age groups as well as promotion from the academy to the senior level (Emmonds et al., 2016). For example, there have been a wealth of studies providing information on the physical running demands for both youth and senior soccer across the ages and stages of development. When examining the available data within youth soccer, there seems to be a gradual trend of increased total distance covered as chronological age groups increase (Saward et al., 2016). Total distances were observed to range from ~5700m in U11 players to ~6700m per game in U16 players (Goto, Morris & Nevill, 2015), followed by a further increase to ~8800m in U18 players (Buchheit et al., 2010). Values for other physical performance characteristics within youth soccer are also reported to follow similar increases with age, with chronologically older players displaying greater maximal sprinting speed (Mendez-Villanueva et al., 2012; Haddadd et al., 2015), completing more high-intensity running distance (Harley et al., 2010; Goto, Morris & Nevill, 2015), and performing a higher number of accelerations and decelerations (Vigh-Larsen, Dalgas & Andersen, 2018). However, consideration should be given to the fact that match durations at younger age groups are much shorter combined with an increase in area per player due to the contrast in pitch dimensions with older age groups (Carling et al., 2008; Casamichana & Castellano, 2010). When this adjustment is made, however, differences in total distance covered between age groups still exist, although less evident (Buchheit et al, 2010). Similarly, when individualised speed thresholds are applied, differences in high-speed distance covered per minute of match play are less evident in elite youth players aged U9-U10 (Goto, Morris & Nevill, 2015) and U12-U16 (Harley et al., 2010). Conversely, U13 youth soccer players have been reported to cover a greater number of repeated sprint sequences (Buchheit et al., 2010b) and cover greater distances at high-intensity speeds (Mendez-Villanueva et al., 2012) than older age groups.

Alongside age, other factors such as playing position and competitive standard of match play also have an influence on the physical running demands of youth soccer (Buchheit et al., 2010; Vieira et al., 2019). Like senior soccer, it has been typically reported that centre backs accumulate the least total distance covered (Mendez-Villanueva *et al*., 2012) and lowest high-intensity distance (Varley et al., 2017; Brito et al., 2017); whereas centre midfielders cover the greatest total distance, and wide midfielders and forwards cover the greatest high-intensity distance and achieve highest max velocity game speeds (Buchheit et al., 2010b; Haddadd et al., 2015; Riccardo & Varde'the, 2017). Match running performance also demonstrates that elite youth players cover greater total distance, high-intensity distance, distance covered per minute and max velocity speeds (Waldron & Murphy 2013; Randers et al., 2014) in comparison to sub-elite/recreational playing standard. Conversely, elite players were observed to complete greater low-speed distance coverage than their sub-elite and recreational peers (Strøyer, Hanson & Klasson, 2004; Waldron & Murphy, 2013). These findings are aligned with those of both Saward et al. (2016) and Goto et al. (2015) who also reported greater low speed running distance covered by retained vs. released youth players. These findings may be explained due to the improvement in tactical awareness and positional understanding that are adopted by the retained group as they progress through the academy structure through a superior standard of coaching and development. However, elite youth players typically display greater physical qualities and demonstrate higher physical performances on the pitch during match-play.

Anaerobic characteristics assist the performance of commonly performed explosive activities such as accelerations, decelerations, changes in direction, jumping, and tackling (Buchheit et al., 2010b; Mendez-Villanueva et al., 2012; Vieira et al., 2019).

Thus, considerable attention is given to strength and power attributes during the development and progression framework of youth soccer players, which is likely the result of the association between strength and power characteristics and specific high-intensity physical activities and actions as mentioned above. Studies have shown a direct relationship between vertical jump height with a player's heading performance (Paoli et al., 2012), while lower limb strength, in the form of maximal back squat performance, has shown a positive correlation with jump height, change of direction, and sprint speed (Wisløff et al., 2004). These findings are aligned with Wing, Turner & Bishop (2020) who reported a direct correlation between squat jump (SJ) and countermovement jump (CMJ) height with a player's ability to succeed in aerial duels, while also illustrating a significant relationship between lower limb strength and a player's ability to successfully win tackles in elite youth soccer. Consequently, development and possession of these qualities is taken into consideration during the development and identification processes of youth soccer (Murtagh et al., 2018), enhancing the commitment to develop these attributes and their effectiveness during high-intensity actions to improve soccer performance.

Physical Fitness Testing in Youth Soccer

Field-based fitness testing methods assist youth soccer practitioners and coaches with both TI and TD. Researchers propose this may be due to the growth in scientific knowledge and ability to implement relevant applied research (Dodd & Newans, 2018; Figueiredo et al., 2014), increases in the physical requirements of professional soccer (Barnes et al., 2014; Murr, Raabe & Höner, 2018; Dodd & Newans, 2018), and advancements in data analytics and technology (Rabbani, Kargarfard & Twist, 2020; Huijgen et al., 2014). The marked increase in the physical demands of training and matches within professional soccer has culminated in greater importance being placed upon training monitoring and recovery protocols in addition to tactical and technical training (Thorpe et al., 2016; Malone et al., 2015). Thus, the role of sports science staff providing expertise and supplementary services to prepare the next generation of elite football players within TI and TD has risen significantly (Dodd & Newans 2018; Murr, Raabe & Höner, 2018).

Within youth soccer academies, it has become necessary to identify essential indicators which can be used to inform a young player's potential of future success in senior soccer (Huijen et al., 2013). As previously discussed, due to the intricacy of predicting future success of youth soccer players, a heuristic model for the classification of talent prediction has been proposed highlighting the importance of physical, physiological, and psychological predictors alongside environmental characteristics (Williams & Reilly, 2000). However, Wilson et al. (2016) acknowledged that most quantitative methods for identifying talented youth players focuses on physical and physiological attributes associated with soccer including measures of endurance, speed, strength, and agility, which appear beneficial in differentiating players. However, these measurements are typically reported using a measurement from a single time point (Williams, Ford & Drust, 2020). Coaches commonly favour selection of young players because of their anthropometric characteristics (Wong et al., 2009). This finding is aligned with Williams, Ford & Drust (2020) who expressed that youth soccer players who progress to become professionals were fitter, faster, more agile, leaner, heavier, and taller during adolescence when compared to their peers in their development programme who did not attain professional status in adulthood. Accordingly, it seems rationale to suggest that physical and physiological factors have gathered significant consideration by researchers and practitioners.

Performing a battery of fitness testing using field- and gym-based tests within a singular testing session has been proposed (Turner et al., 2011) and is often the preferred method within soccer clubs due to it being time-efficient within a training week. A variety of physical fitness tests have been recommended for youth soccer athletes including sport specific aerobic/anaerobic capacity tests, short sprint assessments, measures of muscular power, change of direction/agility tests, and gym-based strength assessments (Hulse et al., 2013). Testing batteries examining physical fitness attributes in relation to soccer training and match-play have predominantly favoured the evaluation of running characteristics of players (Bok & Foster, 2021). As discussed, it is well established that soccer is multi-faceted in its physical requirements (Stølen et al., 2005): however, the aerobic energy system is suggested to be the predominant energy provision utilised for performance during match-play (Doncaster, Iga & Unnithan, 2018). Consequently, assessing endurance running performance has been typically favoured during physical testing batteries of soccer players.

Endurance running ability has historically been assessed using a maximal, incremental treadmill test in a laboratory setting and is typically considered the 'gold standard' for assessing maximal oxygen uptake (VO_{2max}) (Impellizzeri, Rampinini & Marcora, 2005). More recently, field-based measures of endurance have emerged due being more time efficient, resource-saving, and potentially more comparative to soccer demands. Several field-based tests have been used in recent years including the Van Eval test (Mendez-Villanueva et al., 2010), multi-stage 20m shuttle test (Nassis et al., 2010), Yo-Yo Intermittent Recovery test 1 (YYIRT1) (Krustrup et al., 2003; Deprez et al., 2014; Deprez et al., 2015), Yo-Yo Intermittent Recovery test 2 (Bangsbo, Iaia & Krustrup, 2008; Fanchini et al., 2014), 30-15 intermittent fitness test (Buchheit, 2008; Silva et al., 2022) and time-trials (Currell & Jeukendrup, 2008; Clancy et al., 2021). The YYIRT1 is the most commonly implemented endurance testing in youth soccer as evidenced in applied research (Bangsbo, Iaia & Krustrup, 2008; Krustrup et al., 2003; Castagna et al., 2006). This is likely due to the interspersion of short recovery intervals involved in the test that utilise both the aerobic and anaerobic energy systems, mimicking that of soccer training and match-play. Significant correlations between YYIRT1 performance and high-intensity running during match-play have been reported in youth soccer players (Castagna et al., 2009; Castagna et al., 2010; Rebelo et al., 2014; Doncaster, Iga & Unnithan, 2018).

Additionally, Deprez et al. (2014b) reported excellent reproducibility within youth soccer players (aged 11-17 years) alongside observing significant performance differences between different standards of players (elite vs non-elite) across all age groups.

Besides the significance of high-intensity intermittent repeated running within soccer training and matches, excellent maximal sprinting speed, COD/agility, power and strength are also extremely sought after in elite soccer players (Andrzejewski et al., 2013; Pojskic et al., 2018; Wing, Turner & Bishop, 2020). Sprinting ability has been evaluated across both short and long distances to assess acceleration capabilities and maximal running velocity (Haugen & Buchheit, 2016). Most studies assessing sprinting performance use distances in the range of 5 – 40m: however, many researchers illustrate that sprinting ability over short (<10m) and longer (<30m) distances may require independent and specific biomechanical and neuromuscular characteristics. Thus, the selection of applicable distances should be considered when assessing linear speed (Mendez-Villanueva et al., 2011; Haugen et al., 2014). Distances of 5 – 10m are typically chosen when assessing short distance sprint performance due to the prevalence of these distances being reported during match-play (Di Salvo et al., 2010), with these distances being more prevalent in youth soccer (Mendez-Villanueva et al., 2011, 2013) and longer sprints (>20m) detected less often. Laser guns, timing gates and high-speed video, not GPS, are generally expressed as the gold standard for measuring maximal sprinting speed (Kyprianou et al., 2019). However, GPS is frequently used in team sports due to accessibility and it generally being easier to use in daily training and match practice for practitioners. Previous research has shown GPS devices to be both valid and reliable for measuring the quantification of movement demands during both training and match-play (Coutts & Duffield, 2010; Gray et al., 2010). However, the sample rate of the devices, nature of the task and velocity at which individuals are running at have an effect on the validity and reliability of these devices, particularly when analysing movement demands > 20 km·hr^{-1} (Johnston et al., 2012). Research utilising GPS devices has stated it appears that validity improves with higher sample rates (Varley et al., 2012; Johnston et al., 2014). GPS devices (10Hz), such as the devices used in the current study, have previously documented a typical error (CV) of 10.5% for the recording of very high-speed running (>20 km·h^{-1}) during team sports specific movement patterns (Rampinini et al., 2014). Nevertheless, a recent study gathering practitioners' assumptions on the agreeable amount of between-device measurement error displayed that GPS-measured maximal sprinting speed may be equivalent to that recorded by a radar gun (Kyprianou et al., 2019).

The ability of players to efficiently change direction is a highly valued quality of soccer performance (Pojskic et al., 2018), due to its multi-dimensional nature (Stølen et al., 2005). It is important to note the difference between COD and agility as these have been used wrongly interchangeably within literature (Young, Dawson & Henry, 2015). Accordingly, COD has been defined in the literature as the 'skills and abilities needed to change movement direction, velocity or mode'. On the contrary, agility has been defined as 'skills and abilities needed to change direction velocity or mode in response to a stimulus' (De Weese & Nimphius, 2016; Nimphius et al., 2018). When evaluating COD performance, each testing method may vary in length, number of directional changes, angle of direction changes, test duration, and the energy systems utilised (Nimphius et al., 2018). Several tests have been used to assess COD abilities in soccer players including the 505 COD test, modified 505 COD test, and the pro agility test (Nimphius et al., 2018). Most assessments of COD ability utilised within an applied setting incorporate a 180° turn, which places an emphasis on a player's ability to accelerate and decelerate during the test alongside placing demand on eccentric strength capabilities during the COD (Nimphius et al., 2016). Measures of COD at angles of 45° - 90° have also been explored including assessments such as the T-Test, Illinois agility test, and Y-sprint drill (Nimphius et al., 2018). In contrast to tests requiring a 180° turn, assessments requiring a smaller angle of COD allows players to maintain high running speeds whilst changing direction during the test (Spiteri et al., 2015). Research promotes caution when assessing COD performance in youth athletes as data derived from this test may be inconsistent in this sample compared to data reported previously within senior players (Dugdale, Sanders & Hunter, 2020; Taylor et al., 2019). It is suggested by the authors that the beginning of 'adolescent awkwardness', which is common during advanced maturation growth phases occurring during peak height velocity (PHV) (Lloyd et al., 2015), in combination with the complex physical demands of the COD task, may explain the variability in youth player's performance. Thus, specific attention to these potential restrictions within a youth population performance should be deliberated.

The importance strength and power qualities have on numerous physical and technical demands during match play is well documented in the literature (Andrzejewski et al., 2013; Faude et al., 2012; Wing, Turner & Bishop, 2020). Consequently, assessment of both strength and power are commonly proposed by soccer club practitioners and researchers as part of a comprehensive physical testing battery. Muscular strength has been associated with performance of technical actions such as tackling and heading (Wing, Turner & Bishop, 2020). Strength training and assessment for team sports, such as soccer, are typically carried out in a gym environment, assessing either dynamic, isometric, or reactive strength qualities (Suchomel, Nimphius & Stone, 2016). These are commonly assessed through methods such as repetition maximum tests (Comfort et al., 2014) or an isometric mid-thigh pull (Brownlee et al., 2018). These assessments are selected due to the similarities to movements that occur during competition, evaluation of muscles commonly susceptible to injury, and the low time and fatigue expense (Suchomel, Nimphius & Stone, 2016). Within soccer, hamstring function is critical to performance, particularly when exposed to high volumes of sprinting or high-speed running during both training and games (Schache et al., 2012). Reduced hamstring function such as poor strength endurance and low eccentric/isometric strength are associated with hamstring strain incidences in soccer (Green et al., 2020). Thus, incorporating isometric hamstring strength tests may allow for monitoring of the function of this important muscle group as well as presenting an opportunity to examine individual limb and asymmetry (Schache et al., 2011).

Reactive strength qualities are also typically carried out as a performance assessment within a gym environment in soccer. The drop jump test is commonly used within invasion sports to assess players' reactive jump performance and stretch shortening cycle function during plyometric actions (Flanagan, Ebben & Jensen, 2008). This is important in soccer for actions such as jumping and landing, and changing direction, which are commonplace in both training and match-play. Potential limitations of strength assessments have been highlighted for younger athletes due to underdeveloped strength and motor abilities and low training history (Vandendriessche et al., 2012; Vandorpe et al., 2012). Accordingly, considerations should be made to the biological changes that take place during growth and maturation and, as such, certain physical tests may be more suitable for assessment at separate stages of growth and maturation within youth soccer players (Towlson et al., 2018).

Finally, power characteristics are also an important physical quality that are essential to successful performance within soccer. The assessment of these qualities are more commonly applied within a practical setting in youth soccer comparative to those of strength (Paul & Nassis, 2015). Power characteristics are frequently displayed during jumping actions, rapid changes of direction or velocity and technical actions such as shooting or long-passing during training and match-play (Stølen et al., 2005; Di Salvo et al., 2009; Faude et al., 2012). Therefore, assessments that allow for evaluation and interpretation of power characteristics applicable to these activities and actions are generally used within soccer clubs. Predominantly, the most featured assessment of power within soccer clubs is the CMJ. The CMJ assesses players' vertical jump height and provides a dynamic assessment of lower and whole-body power (Paul & Nassis, 2015). Like strength, the stability of power characteristics during the developmental years has been debated within scientific literature (Lloyd et al., 2012), likely due to the impact of maturational effects on both power and strength-based qualities. For example, it was reported among youth soccer players between U9 – U21 that vertical and horizontal jump measures only discriminate at mid-and post-PHV between elite vs control players, querying stability of these measures within pre-PHV youth soccer players (Murtagh et al., 2018). Despite this, substantial research exists illustrating power to be an essential characteristic in relation to various activities during soccer training and match-play (Deprez et al., 2015), thus warranting applicable and longitudinal assessment during monitoring and testing.

Reliability, Validity and Sensitivity of Testing

In soccer, predictive variables have an intricate interaction, each with a distinct degree of impact upon the outcome variable which can include physical, technical, tactical, and psychological factors (Reilly & Gilbourne, 2003). Performance testing methods allow researchers and practitioners to conduct sport-specific assessments in a controlled scientific environment, allowing soccer clubs to measure changes in performance over multiple timepoints or longitudinally. Thus, when implementing a testing battery for assessing physical fitness in soccer, consideration must be made to ensure that chosen tests are specific to sporting demands and individual requirements, while establishing high quality measures of reliability, validity, and sensitivity (Svensson & Drust, 2005). An abundance of research has been carried out to assess the quality of testing procedures used within soccer and although the reliability and validity of these measures have been conducted in senior athletes, these have historically been implemented within a youth sample based upon this unrepresentative validation (Paul & Nassis, 2015). Published reports have shown that youth athletes have substantial physical and biological differences and abilities compared to more mature and senior athletes (Dugdale, 2019; Matos & Winsley, 2007, Pearson et al., 2006). Accordingly, these discrepancies should be recognised when establishing measures of fitness testing.

The reliability of a test refers to the consistency and reproducibility of performance when executed on repetitive occasions by the same participant or group. Acceptable reliability is a critical element within fitness testing in soccer to ensure data that informs the TD process is meaningful (Hopkins, Schabort & Hawley, 2001). From an applied perspective, acceptable reliability is important as tests with poor reliability lack accuracy for the evaluation of performance and makes it challenging to monitor real changes in performance between testing sessions (Hopkins, 2000). The reporting of reliability can be expressed in various ways (Hopkins, 2000) such as: (i) the intraclass correlation (ICC), which describes how strongly units in the same group resemble one another, (ii) the coefficient of variation (CV), which articulates the standard deviation (SD) of the repeated measurements as a percentage of the mean and (iii) cohen's d effect sizes (ES), which is used to indicate standardised difference between two means (Currell & Jeukendrup, 2008). Reliability of testing may also be sensitive to various influential factors including inter-trial time, duration of test, testing order, participant training and fitness status, and the type and suitability of test being conducted.

Validity can be as whether a test really measures that what it intends to measure. Validity can be summarised as three different types: (i) logical validity; which specifies whether a test measurement does actually measure what it intends to measure, (ii) criterion validity; which can be divided into two subcategories: concurrent validity in which the performance protocol is correlated with the criterion measure, and predictive validity, which includes utilizing a performance protocol to predict performance, and (iii) construct validity; which refers to the extent to which a protocol measures a hypothetical construct, such as comparison of two different groups or sports performance. (Paul & Nassis, 2015). Finally, the sensitivity of a testing protocol determines the usefulness of the tests and its ability to detect and measure systematic changes at both group and individual level (Beckerman et al., 2001). The smallest worthwhile change (SMC), minimal detectable change (MDC) and standard error of measurement (SEM) are all regarded as valuable benchmarks on the scale of test sensitivity, which assists with the understanding of changes in scores (Beckerman et al., 2001).

Several studies have assessed the reliability of field-based tests within youth soccer players. Field based tests typically involve assessments of aerobic/anaerobic capacity, maximum velocity, COD ability and jumping performance. Enright et al. (2018) reported high levels of reproducibility (CV = 0.3 – 4.3%) across all field-based tests in a cohort of elite level English Premier League academy players. However, this cohort of players was limited to senior academy players only (mean ± SD: age, 18.3 ± 0.2 years). Similarly, Dugdale et al. (2019) demonstrated high measures of reliability of physical performance of 11–17-year-old youth soccer players (ICC = 0.83 0- 0.97; $p<0.01$) across five field-based tests. However, when assessing COD performance, weaker reliability was shown in the younger cohort of participants (ICC = 0.57 – 0.79; $p<0.01$). It is important to recognise, however, that this study did not account for biological maturity within their sample and only assessed players acutely, questioning the prognostic ability of their selected tests. As previously discussed, the YYIRT1 has shown to report excellent reproducibility across 11–17-year-old youth soccer players (ICC = 0.82 - 0.94). However, there was also greater variability observed in the performance measures of the younger participants within the study (U13: CV = 17.3%; U17: CV = 7.9%) (Deprez et al., 2014). Similar findings were reported one year later observing high reproducibility (ICC = 0.87 – 0.95) and reliability (CV = 3.0% - 7.5%) of the YYIRT1 within young high-level soccer player (Deprez et al., 2015). Several studies have also showed that COD and agility tests such as 5-0-5, modified 5-0-5 and Y-sprint test have demonstrated good levels of reliability among youth soccer players (Dugdale et al., 2019; Taylor et al., 2019; Pojskic et al., 2018). For example, Dugdale, Sanders & Hunter (2020) report good reliability (ICC = 0.81–0.91; CV = 1.2–2.0; $p < 0.01$) of COD and agility tests when assessing eighty-six high level youth soccer players. However, small-to-moderate negative relationships were observed between age/maturity and between trial performance for the Y-sprint tests. These findings may suggest that strength capacities that are not yet fully developed, deficient motor coordination, and limited physical literacy associated with younger and less mature players may culminate in larger inconsistencies in test performance (Lloyd et al., 2013).

Previous research in youth soccer has shown that intermittent running tests such as the YYIRT1 has reported large to very large significant correlations with total distance covered (r = 0.53 – 0.65) (Krustrup et al., 2003; Krustrup et al., 2005; Castagna et al., 2009), high-intensity running (r = 0.56 – 0.76) (Bangsbo et al., 2008; Rebelo et al., 2014; Doncaster et al., 2016), very high-intensity running (r = 0.59) (Doncaster et al., 2016) and sprinting (r = 0.63 and 0.76) (Castagna et al., 2010; Rebelo et al., 2014) performed during match-play, which appears to support the ecological validity of the test (Castagna, Krustrup & Póvoas, 2020). Field-based fitness tests have also been reported to be successful at distinguishing between different age groups of players (Hulse et al., 2012) and different competitive standards (Dugdale, Sanders & Hunter, 2019). Thus, suggesting that field-based testing batteries are able to demonstrate both logical and construct validity.

In sum, the majority of previous research seeking to explore the reliability and validity of fitness tests in youth soccer players have either measured test reliability for restricted age groups (i.e., senior academy players), used limited testing batteries (Rebelo et al., 2012; Le Gall et al., 2010; Thomas et al., 2009) or don’t account for biological maturity (Dugdale, et al., 2019). This has led to the predicted value and validity of the frequently used physical fitness measures and testing batteries within youth athletes to be questioned by researchers (Murr, Raabe & Höner, 2018; Sarmento et al., 2018). However, academies may have their own testing batteries and selection of tests that they may use in-house. Therefore, ensuring these are validated and appropriate is necessary for effective interpretation of results within youth soccer academies.

Growth and Maturation in Youth Soccer

Within soccer academies, development of youth soccer players and TI are both multifaceted and complex in nature (Towlson et al., 2019, 2021; Larkin & O'Connor, 2017). In soccer, and other sports, players are grouped by chronological age. However, players of the same age can differ by several years in biological maturity (Malina, Bouchard & Bar-Or, 2004). Biological maturation can be referred to as the process of progression towards achieving the mature state, which involves the timing and tempo of the maturation process. The timing and tempo of growth are highly individual and have a non-linear relationship with decimal age across adolescence (Philippaerts et al., 2006). This non-linear relationship between the players development in stature and decimal age is caused by the onset, and difference in timing, of PHV (Malina et al., 2012). The tempo of growth in adolescent soccer players is estimated to elicit a phase of accelerated growth (approximately 7.5-9.7 cm/year) between 10 and 16 years of age (Towlson et al., 2018). The timing of PHV is of particular significance within soccer academies, as it is common within chronological age groups which span from U11-U16, ages typically comprising captured during the academy TD process. Further, it is well documented that brief, maturity-related differences in body mass, stature, and improvements in physical fitness characteristics have been documented to have a significant impact on the selection and de-selection processes implemented by soccer academies (Figueiredo et al., 2009). As a result of advanced anthropometric values (i.e. stature and body mass) and performance characteristics (strength, speed and power), a maturity bias exists within soccer academies which is expressed by the overrepresentation of early-maturing players within soccer academies (Johnson, Farooq & Whiteley, 2017; Hill et al., 2020).

Resultant of criteria enforced at governing body-level, it is now an essential requirement to gather, monitor and evaluate maturity data to inform conclusions of individual TD programmes and decisions. The most common protocol utilized within soccer academies to estimate maturation status, estimate time from PHV, and to predict adult stature is through the use of somatic equations derived from anthropometric measurements (Khamis & Roche, 1994; Moore et al., 2015). The "Mirwald equation" is commonly used in soccer academies which is suggested to predict the age of PHV (Mirwald et al., 2002). This equation is calculated by gathering three somatic anthropometric measurements including standing height, seated height, and leg length combined with body mass, which is then integrated into a sex-specific calculation which estimates the distance an individual is from the point of PHV (Salter et al., 2022). However, this equation has been found to overestimate PHV ages for early maturing individuals, and underestimated for late-maturing individuals, both of which are prevalent within younger and older chronological age groups within soccer academies. Khamis and Roche (1994) propose an equation to predict the final estimated adult stature, which does so by expressing the progress towards adult stature as a percentage (PAH%). This equation uses many of the same anthropometric measurements as the Mirwald equation, such as standing height and body mass. However, in addition to this, the player's birth parents' accurate stature is required to determine mid-parent stature, which can be combined with the current stature and body mass of the young individual to estimate maturity status (Khamis and Roche, 1994). This equation utilises smoothed values of the intercept and regression coefficients using data from the FELS method. The FELS method uses radiographs of the individual's left-hand wrist, which provides a more detailed analysis of bone morphology. This method then uses statistics established on odds ratios to conclude the most appropriate indicator of skeletal age for the young individuals decimal age (Chumela, Roche & Thissen, 1989). However, this method is often never utilised within youth soccer academies as they demonstrate clear drawbacks which include exposing children to radiation; require high level of expertise to conduct; and are costly, invasive and time intensive (Marshall and Tanner, 1970). The Khamis-Roche method is therefore the preferred method among many soccer academies, including national governing bodies of the English Premier League and EPPP, where this data can be used to compare against age and sex-specific standards to ascertain the magnitude to which a child is advanced or delayed in maturation. Using PAH% at the time of gathering measurements provides an opportunity to group players into maturity categories: pre-PHV (< 85 to < 90 PAH%), circa-PHV (≥ 90 - < 95 PAH%) and post-PHV (≥ 95 PAH%) (Cumming et al., 2017). This categorisation may be useful for both coaches and practitioners within soccer academies to implement specific maturity interventions, such as reduction in training load to reduce injury risk (Johnson et al., 2022) or produce maturation reports for key stakeholders within the academy which may then inform talent selection/deselection decisions (Cumming et al., 2017). However, it must be noted that these equations to estimate maturity status are subject to associated error, as they are predictive measures of maturity status and not a direct measure.

Differences in maturity status and the timing at which maturation occurs with individuals has been demonstrated to hold significance on the physical and athletic development of youth soccer players (Clemente et al., 2021). Players who mature in advance of their peers (early maturers) undergo the adolescent growth spurt at an earlier age and, thus, obtain an apparent advantage in terms of stature and physical athleticism (Johnson, Farooq & Whiteley, 2017). Consequently, these players are typically taller, heavier, stronger, more powerful, and quicker than those who are considered late maturers (Malina et al., 2015; Johnson, Farooq & Whiteley, 2017). Unsurprisingly, these players are more likely to outperform their peers on tests of strength, speed, and power (Meylan et al., 2010), and, therefore, more inclined to succeed in a sport like soccer which utilises these physical attributes. Consequently, early maturing players are retained within and recruited into soccer academies, which results in better access to training resources, elite coaching and a greater investment into their development (Malina et al., 2015). This also presents these players with greater exposure to elite level programmes, thus competing against a higher standard of competition. Conversely, for talented late-maturing players it is necessary to develop superior technical, tactical, and psychological skills in order to compete with their early maturing peers. However, these players still tend to be overlooked, deselected, and denied developmental opportunities before they have the chance to mature and develop physically (Colbey, 2016; Hill et al., 2020).

Previous research has illustrated the effect that maturity status may have on physical performance characteristics of youth soccer players. Early maturing players are more likely to cover greater high intensity running distances during match-play in comparison to their late maturing peers, while also attaining higher max velocity running speeds, and having greater frequency of involvement in high-intensity and repetitive high-intensity activities (Buchheit & Mendez-Villanueva, 2014). This is reiterated by Francini et al. (2019), who revealed that moderate associations occurred between PHV status and high-speed distances covered during soccer match-play. Moreover, a recent study by Parr et al. (2020) investigated the effect of maturity on physical performance in elite youth soccer players from an English Premier League academy. This study found that maturity status was positively associated with performance on the CMJ, change of direction, and the 5m and 20m sprint tests. Similarly, Radnor et al. (2021), reported that early maturers out-performed both on-time and late-maturers in sprint performance over 30m, highlighting a significant association between maturity and sprint performance across U12 – U16 youth soccer players.

Accordingly, attention must be highlighted to the timing in relation to biological maturation and chronological age progression, along with the different inter-individual rates at which these occur, when analysing the characteristics of youth soccer players.

Practitioners within soccer academies should be encouraged to monitor growth and maturation from the U11 age group until U18 within their academy to help inform and understand the physical performance characteristics of youth players whilst accounting for these inter-individual differences in growth and development. It is important to consider that maturity may influence the physical performance of youth players, with early-maturers possessing a significant advantage over on-time and late-maturers. Therefore, practitioners and coaches should be encouraged to recognise these individual differences in maturation when it comes to selection/de-selection processes for TI and TD.

Although the data gathered from methods of estimating maturity, such as the Khamis-Roche and Mirwald equations, are useful for practitioners involved in soccer academies, it is important to recognise the associated error. The Khamis-Roche method has been reported to have a median error of approximately just over 2cm in boys and just under 2cm in girls across the age span of 4.0 – 17.5 years of age (Cumming et al., 2018). The associated error within these methods therefore may result in individuals being inaccurately categorised in relation to their maturation status (Cumming et al., 2017), as a consequence of systematic error rather than biological maturity. Subsequently, these errors may be slightly elevated when birth parent’s height is self-reported or unavailable. Therefore, the accuracy and conformity of the combined anthropometric data values is of absolute importance if practitioners are to use this method to categorise their player’s and inform their long-term physical development.

Perceptions of Key stakeholders within Soccer Academies

As previously discussed, developing and identifying young soccer players is a crucial aspect of a key stakeholder’s role, particularly coaches, within elite soccer academies (Williams & Reilly, 2000; Larkin & O’Connor, 2017). It is considered that the TD processes within academies are both complex and multidimensional in nature (Saramento et al., 2018). Soccer academies are typically constructed of multidisciplinary teams, including coaches, sports scientists, physical performance coaches, teachers, sports psychologists and additional support staff, who must work together closely to develop these talented young soccer players and build effective learning environments in which they can develop (Kingston et al., 2018; Williams, Ford & Drust, 2020). Professional soccer clubs operate their academies to provide for youth players beginning as young as 4 years-of-age and progress through the developmental phases towards professional transition at around 18 years-of-age. For coaches and recruitment staff, it is desirable to recruit players as early as possible which facilitates prolonged exposure to the TD processes to develop the skills and attributes essential to succeed when transitioning to the professional level (Burgees and Naughton, 2010; Williams, Ford & Drust, 2020). However, most youth soccer players fail to transition from the youth team level to professional/first team (Anderson and Miller, 2011), with a small percentage of youth players being rewarded with a professional contract (Grossman and Lames, 2015).

The multidisciplinary character of the TD process has been reflected in several framework models such as the Locking Wheel Nut Model (Kelly, Williams & Wilson, 2018), Athletic Talent Development Environment model (Henriksen, Stambulova & Roessler, 2010), Athletic Career Transition model (Stambulova, 2016), and the football association's Four Corner Model (FCM) (The Football Association, 2020). The FCM model is often prevalent within professional soccer academy organisations which encourages for the development and assessment of youth players in relation to four different concepts which include technical/tactical, physical, psychological, and social attributes, as outlined in previous research by Williams and Reilly (2000). Towlson et al. (2018), utilized the FCM within their qualitative methodology while establishing the perceived importance that practitioners within soccer academies placed on the four key pillars during player selection. This study found that psychological factors were rated significantly higher than technical/tactical, physical, and social factors. Additionally, this study identified that sociological and physical factors were valued significantly more by youth phase practitioners compared to the foundation phase. Similarly, Kelly et al. (2021) applied the same FCM model in a quantitative analysis of determinants distinguishing those who 'play-up' an age group. In the foundation phase, social and technical/tactical factors were suggested to differentiate those who played up compared to those who did not, whereas at the youth phase there was no significant factor differentiating the progression of youth players with factors from all four pillars contributing to those who play-up. It is recommended by researchers that a holistic multidisciplinary approach is taken by coaches with regards to TI and TD (Unnithan et al., 2012).

Studies exploring the rationale and perceptions in relation to progression of youth players through the phases within an academy structure to professional are generally limited. A worldwide questionnaire-based study by Lundqvist et al. (2022) found that key stakeholders within youth soccer academies documented a long-term development strategy, specialised roles supporting player transition, and exposure to varying playing styles as important factors on the success of youth to professional transition. Additionally, Mitchell et al. (2020) gave an insight into the barriers associated with transition within the soccer academy structure through the perceptions of key stakeholders involved in the organisation. Findings suggest four specific factors associated with youth to senior progression which include: 1) working practices (i.e. increased training intensity); 2) cultural climate (i.e. limited playing opportunities); 3) occupational hazards (i.e. injury), and 4) social issues (i.e. living away from home). This suggests that youth players transitioning through the phases to professional/senior soccer may require and benefit from individualised resources and support from practitioners involved in youth soccer. Finally, McGuigan et al. (2023) reported key stakeholders of an elite academy in the UK perceptions of both facilitators and barriers in relation to youth soccer players transition from youth to professional first team. These authors noted key facilitators linked to player transition including exceptional physical prowess, overcoming adversity, and excellent technical ability. On the contrary, a lack of opportunity, lack of development-specific coaching, and significantly well-paid youth contracts were seen as barriers to progression. With professional soccer academies investing significant time, money, and resources into TI and TD of youth soccer players, understanding key stakeholders' perceptions on the processes involved in this domain is warranted. Multiple perspectives of these crucial determinants may help to develop and support existing methods to facilitate talented youth player's successful transition through the academy phases to professional soccer.

Literature Review Summary

This literature review has illustrated the current physical demands and use of physical fitness testing and monitoring within youth soccer players, and the possible utilization of physical fitness testing within both TI and TD. Most soccer clubs develop their own testing battery to develop players according to their own philosophy and playing styles. Therefore, ensuring accuracy of this within this population is crucial. Understanding the applicability and usefulness of the physical fitness testing protocol within the processes of TI and TD would provide soccer clubs with beneficial information. Additionally, given the many physical and biological changes that occur during the formative years of adolescence, as well as the substantial discrepancies that exist between youth and senior soccer, further research is necessary to validate suitable measures across chronological age groups and biological maturity status within an academy setting. Congruently, by gaining a better understanding of the rationale and perception for testing methods and processes from key stakeholders involved in the academy youth structures, it may assist with the multidisciplinary collaboration.

Project Aims

The aim of this thesis is to review the physical fitness testing practices with a Scottish Premier League Soccer academy. This will be conducted by:

(i) Examining the reliability of a current testing battery across the entire age range of the club's academy TD programme (U13-U18).

(ii) Assessing the construct validity of the testing battery to discriminate between both chronological age groups (U13-U18) and maturity status (i.e., Pre, Circa, & Post PHV).

(iii) Assessing the sensitivity of the current testing battery to identify meaningful changes following a period of one competitive season across all age groups.

(iv) And establish the rationale for the current fitness testing battery through the use of focus group interviews with key stakeholders within the academy.

Methodology

Participants

Players

A total of fifty-nine male Scottish youth soccer players (mean ± SD: age 15.3 ± 1.5 years; stature 169.0 ± 11.2 cm; body mass 57.7 ± 12.3 kg) from a Scottish Premier League academy volunteered to participate. Participants spanned six chronological age brackets (U13, U14, U15, U16, U17 & U18) identified by the Club Academy Scotland (CAS) structure of the Scottish Football Association (SFA). Participants were completing between 4-5 prescribed training sessions per week (depending on age) including technical, tactical, strength and conditioning, speed, agility, and aerobic conditioning training. Participants were ineligible if they were currently injured or had been injured within the previous 3 months. Participants and their parents/guardians had the process of the study explained to them through a meeting with each individual age group, followed by providing each individual being with an information sheet for them and their parents/guardians (Appendix 1). Following this, individuals who agreed to take part in the study were then provided with consent forms, which they were instructed to read through and return signed, along with parent/guardian signature, when they had read and fully understood the information provided (Appendix 2). Participants were made aware that participation in the study was completely voluntary and that if they declined to participate, it would have no effect on their playing time, training experience, their relationships with the coaches and staff or anything else involving their time spent with the club. Participants were also informed that they were able to withdraw their participation from the project at any point until the gathered data had been anonymised. Once the data has been anonymised the participants were no longer be able to withdraw from the study.

Stakeholders

Eight male key stakeholders currently working within the football club's youth academy volunteered to participate in focus groups for this study. One stakeholder left the club during this period of time, while another staff member could not participate due to personal reasons resulting in data being collected from a total of six staff members (mean ± SD: age 38.8 ± 11.8 years; mean ± SD: coaching experience 8.58 ± 6.79 years). Informed consent was gained from all participants along with providing participant information sheets containing detailed explanation of the focus groups (Appendix 3). Participant roles included head of academy, head of performance, two academy physical performance coaches, and two technical coaches from the academy age groups. Participants were eligible if they were currently working within the club academy and had held their current position at the club for longer than one year.

Procedure

Data were collected from three fitness testing sessions across a 1-year period. The first fitness testing session took place as part of the clubs quarterly testing procedure, the second fitness testing session took place between five and fourteen days after the first testing session, and the third fitness testing session was conducted one year after the first testing session, again as part of the club's quarterly scheduled testing sessions throughout the season (**Figure 1**). To assess the reliability of the testing battery for our sample, performance between fitness testing session one and two were compared. To assess validity of the testing battery for our sample, performance was compared between chronological age groups and biological maturity status using data obtained from fitness testing session one. To assess sensitivity of the fitness testing battery for our sample, intra-participant performance was compared between fitness testing session one and fitness testing session three. Finally, to explore the rationale for, and perceptions of, the current testing battery according to the key stakeholders within the club's academy, two focus groups were conducted with: 1) Technical coaches, and 2) Physical performance coaches.

Data was collected from 5 fitness tests that are currently used as physical performance measures within the football club. The fitness tests included the Countermovement Jump (CMJ) with both Jump Height (cm) and Eccentric Braking Strength (bw.kg) results being recorded; Drop Jump (DJ), which measured participants' Reactive Strength Index (RSI); Isometric Hamstring Strength using the Nordbord (N); Flying 20m Sprint, which measured participants' maximum velocity (m/s) over 20m, and a 1000m Time Trial, measuring participants' time to completion (s). To account for circadian variability, both testing sessions took place at the same time of day and during players' normal training hours. Testing was completed a minimum of 48 hours following a competitive game, and players restrained from performing any strenuous exercise within 24 hours prior.

Gym-based testing was conducted in the football club gymnasium and field-based testing was conducted on a 4G artificial surface, also at the club training ground. Prior to both testing sessions participants completed a standardised warm up consisting of light aerobic activity, dynamic stretching, muscle activation exercises and progressive sprints. Following the standardised warm up, participants received verbal instructions and demonstrations immediately prior to conducting 1-2 familiarisation attempts for each test. Participants then competed 3 attempts of each test (unless stated otherwise), with the best attempt being selected for analysis. Where multiple attempts were conducted, recovery intervals were standardised as 30 seconds, with a 5-minute recovery interval between tests. Testing order and procedure remained the same on all testing occasions. The research team and practitioners from the academy remained constant across all testing sessions, with practitioners and researchers gathering data from the same fitness tests across each session.

1st Testing Session	• The first testing sessions took place on Wednesday & Thursday between 17:00 & 19:30 for all age groups. This was scheduled as part of the clubs quarterly testing procedure.
Procedure	• 13's, 16's & 18s participated in testing on Wednesday, with 14s & 15s testing on Thursday. • This follows the current allocated gym session times for each age group. • All participants began testing by completing a warm-up consisting of dynamic stretching and muscular activation exercises.
Indoor Testing Order	• Stature and Body Mass • Countermovement Jump (CMJ) • Drop Jump • Isometric Hamstring Strength
Outdoor Testing	• Participants proceeded from the gym out onto the 4G pitch at the training ground. • This began with light aerobic activity, dynamic stretching and advanced into progressive sprints.
Outdoor Testing Order	• Flying 20m Sprint • 1000m Time Trial • Total duration for all testing = 60 minutes
2nd Testing Session	• The 2nd testing session was completed following a washout period of 5-14 days after the 1st testing session • To account for circadian variability, both testing sessions took place at the same time of day and during player's normal training session hours mirroring the 1st testing session.
3rd Testing Session	• The 3rd testing session was completed as part of the clubs quarterly testing schedule. This was completed following a period of >6 months to assess the sensitivity of the current testing battery across all age groups.
Focus Group Interview 1	• Focus Group interviews were conducted in a private meeting room within the clubs training centre. • The first focus group involved the Physical Performance coaches which took place Friday 30th June
Focus Group Interview 2	• The second focus group involved the Head of Academy and Technical coaching staff which took was conducted on Monday 10th July

Figure 1. Schematic timeline for data collection

Measures

Anthropometric Data

Standing height and seated height was measured using a free-standing stadiometer (Seca, Birmingham, UK) and body mass was calculated using digital floor scales (Seca, Birmingham, UK). Measurements were collected to the nearest 0.1cm or 0.1kg. Participants were instructed to remove footwear and any additional clothing which did not include training socks, shorts and t-shirt, before completing stature and body mass collection.

Estimation of Maturity Status

Utilising the Khamis & Roche (1994) method of maturity estimation, the football club requested each player's parent completed a self-report form to present their standing stature in order to determine mid-parent stature upon their child joining the club. However, not all parent's provided these forms which meant it wasn't possible to obtain the predicted adult height for all participants. Following player anthropometric measurements, the players stature, body mass, chronological age and parent's stature was used to predict the adult stature of each participant (Khamis & Roche, 1994). Each participants present stature was then defined as a percentage of their predicted adult stature (%PAH) and the maturity status (pre-, circa- and post-PHV) was determined for each of the measurement points (Cumming et al., 2017). Participants were categorised as pre-PHV (<85% and ≥85% to <90 PAH%), circa-PHV (≥ 90 - < 95 PAH%) and post-PHV (≥ 95 PAH%) as per calculations used by the academy. The Khamis Roche formula utilised is as follows: - Predicated Adult Height formula $= \beta_o$ + stature* β_1 + body mass*(β_2) + corrected mid-parent stature *β_3.

Countermovement Jump (CMJ)

Data for participants' CMJ performance was captured on ForceDecks FDMax Dual Force Platforms (VALD Performance, Brisbane, Queensland, Australia). Force plate data was sampled at 1000 Hz and analysed via ForceDecks software. Dimensions of force platforms were 35 x 70cm. Prior to commencing, participants completed practice jump attempts, increasing in intensity (Barker et al., 2018). Prior to commencement of recorded jumps, force plates were zeroed and participants instructed to stand still on force plates for 2-3 seconds until their bodyweight is calibrated. Participants were then instructed to perform the CMJ with equal weight on both force plates with their hands on their hips (akimbo position). Following a verbal cue, participants were instructed to drop to a self-selected countermovement depth as fast as possible, jump vertically as high and as fast as possible, and land back onto the force plates. Participants were given 3 attempts to obtain their maximum jump height with 30 seconds of rest between each trial. Two members of the research team visually supervised each attempt to determine failed attempts that occurred. Participants were instructed to keep their hands on their hips at all times, maintain extension in the hip, knee and ankles joints during their time in the air and land with each foot on the designated force plate during landing. Failure to adhere to any of these instructions resulted in a failed attempt. The CMJ test recorded participants' jump height (cm) and mean eccentric power (W.kg). The maximum value from all 3 jumps was recorded and used for analysis.

Drop Jump (DJ)

Participants also performed the DJ test on ForceDecks FDMax Dual Force Platforms (VALD Performance, Brisbane, Queensland, Australia). Force plate data was sampled, calibrated, and analysed via the same process as the CMJ. Before performing the DJ, participants were instructed to stand on a box at a height of 30cm with their arms adopting the akimbo position. Participants were instructed to step off the box and perform a typical

DJ, minimizing ground contact time and immediately execute a maximal vertical jump, landing back on the force platforms with both feet on the same platform and position as take-off. Participants were given 3 attempts to obtain their maximum RSI with at least 30 seconds of rest between each attempt. Two members of the research team visually supervised each attempt to determine failed attempts. Failure to adhere to instructions given during each attempt resulted in a failed attempt.

Isometric Hamstring Strength

Isometric Hamstring Strength was assessed using the prone isometric hamstring strength test. This was used to record the peak force (N.kg) produced by the participants using the NordBord (VALD Performance, Brisbane, Queensland, Australia). Participants were instructed to position themselves in a kneeling position on the padded board with the ankles secured immediately superior to the lateral malleolus by individual ankle braces attached to custom-made uniaxial load cells (Delphi Force Measurement, Gold Coast, Australia) with wireless data acquisition capabilities (Mantracourt, Devon, United Kingdom). The position of the participants knees on the padded board was recorded for each individual before commencing the test. Participants were then instructed to place their elbows and forearms on a 20cm box adjacent to the NordBord, with their knees remaining on the padded board. The 20cm box was adjusted to address variations in participants' anatomical dimensions and to ensure hip flexion angle remained consistent across all participants. Once in position, instructions were given for participants to pull up into the ankle braces with maximal effort for 3-5 seconds, keeping their trunk in a neutral position throughout and hips fixed in the same position with a maximum angle of 30° hip flexion. Participants were verbally encouraged to provide maximal effort throughout each attempt. Participants performed two isometric efforts with at least 30 seconds recovery between each attempt. The maximal effort for each limb was recorded for analysis. Two members of the research team visually supervised each attempt to determine failed attempts that occurred. Failure to adhere to instructions given during each attempt results in a failed attempt.

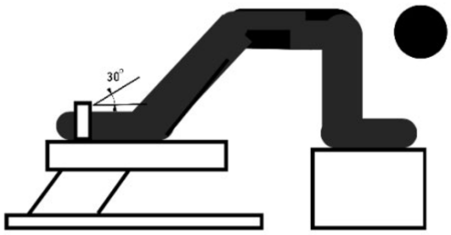
a) [redacted] b) 

Figure 2. *a) Demonstration of the performance of a prone isometric hamstring strength test being performed; b) diagram of the set up for the prone isometric hamstring strength test.*

Flying 20m Sprint

The flying 20m sprint test was used to record the participants maximal sprinting speed (MSS) as peak running velocity (m/s). For each trial, MSS was measured using the Catapult Vector Pro Global Positioning System (GPS) unit (10 Hz, Catapult Innovations, Melbourne Australia). The GPS devices also included a tri-axial accelerometer, gyroscope and magnetometer sampling at 100Hz. Each participant was assigned one Vector GPS unit provided by the research team and wore the same device during all testing sessions throughout the study for consistency. Each GPS unit was identical in size (81mm x 43mm x 16mm) and was attached an individual vest to each participant. All participants were given a numbered vest, with the GPS unit sitting between the participants scapulae and ensuring the GPS antenna were fully exposed. All devices were activated 15 minutes before the warm up and data collection took place to support acquisition of satellite signals in accordance with Catapult manufacture instructions (Duffield et al., 2010). All attempts included a 20m fly-in sprint to omit the time it took to reach the MSS which aligned with previous literature recommendations when analysing speed accuracy using GPS units (Johnston et al., 2012; Alphin et al., 2020).

Participants were instructed to begin at the starting line and on command by the researcher, build into a sprint for the first 20m fly-in and maintain a sprint for the subsequent 20m. Participants were verbally encouraged to provide maximal effort throughout each repetition. After each completed attempt participants were instructed to walk back to the start line, followed by a timed recovery of at least 5-minutes to ensure adequate rest between each maximal attempt. Following the 5-minute recovery, participants were instructed to repeat the test on the researcher's command. Participants completed two attempts of the test with their MSS being recorded for analysis. Following recording of data collection, GPS data were downloaded to a computer and analysed using the manufacturers software (Catapult Openfield Software, Version 3.10.5). At this stage the data is cleaned and clipped to training time ranges and then sent to a central application maintained in the cloud and additionally to a dedicated database.

1000m Time Trial

The 1000m time trial test was used to assess the participants aerobic performance. Similar to the flying 20m sprint, participants wore a Catapult Vector GPS unit (10 Hz, Catapult Innovations, Melbourne Australia). Each participant was assigned the same Vector GPS unit provided by the research team for the flying 20m sprint and wore the same device during all testing sessions throughout the study. The 1000m time trial consists of a maximal 10 x 100m shuttle run. The shuttle track was divided into lanes by large cones at either end. To ensure the correct distance was achieved, participants were instructed to touch the cone as they changed direction at either end. Researchers were based at each end to ensure participants completed the full length and did not stop short on their change of direction. Trials were performed on a 4G artificial surface, and individual scores were recorded as time taken to complete the test in seconds (s) recorded by a manual stopwatch, and if required, confirmed by video analysis (all trials were filmed).

Focus Groups

Focus group interviews were split into two groups to allow all staff to speak freely and not have any hesitations about their answers within the discussion that may not align with other staff members involved in different performance departments within the academy. The first focus group contained the head of performance and physical performance coaches (n = 3), and the second group included the head of academy and technical coaching staff (n = 3). Focus groups were conducted within a private meeting room within the club's training ground. Focus groups were recorded using Microsoft Teams through the researcher's laptop which was placed in the middle of a centralised table, with a Dictaphone being used as a back-up recording. The process was facilitated to explore identified themes and relevant issues and ensured fluent discussion and richness of the data (Patton, 2002). The focus groups were controlled around main core questions exploring participants' general philosophy, aims, decision making, and opinions in relation to the physical fitness testing processes within the academy in a semi-structured interview style (Appendix 4; Appendix 5). The researcher used prompts and probes for each individual during questioning to encourage elaboration, further explore emerging themes, and to ensure the researcher accurately interpreted the responses from all individuals. Each focus group lasted between 35 and 40 minutes, with 74 minutes of interview data collected in total. Focus groups proceeded until participants had no further information or comments to add. Transcripts were made available on request to all staff members who participated in the focus groups.

Data Analysis

Statistical Analysis

A two-way random effects intra-class correlation coefficient (ICC) with absolute agreement and coefficient of variation (CV) assessed relative test-retest reliability. Before proceeding with analysis, assumption of normality was verified using the Shapiro-Wilk test. Standard effect sizes (ES), reported as Cohen's *d* using the pooled standard deviation (SD), was calculated to determine the magnitude of the test-retest differences with threshold values interpreted as $\leq$_0.2 (small), 0.2 $\leq$ 0.5 (moderate), and $\geq$ 0.8 large) (Cohen, 2013; Hopkins et al., 2009). The tests were assumed reliable if they met the subsequent criteria: - good-excellent reliability (ICC > 0.80) and moderate CV ($\leq$ 10%) (Atkinson & Neville, 1998; Hopkins, 2000). Chronological age group and biological maturity status were compared via a one-way analysis of variance (ANOVA), with a Bonferroni post-hoc test being implemented to identify differences between groups. Sensitivity analyses was conducted by comparing intra-participant performance using a time-period of 1-year via a paired samples t-test. Statistical significance was set at $p < 0.05$.

Focus Group Analysis

Focus group data analysis was conducted using a framework analysis, which facilitated a systematic approach to framework advancement and allowed the researcher to compare focus group data sets. This involved a six-stage procedure to develop themes and concepts from the data set (Ritchie & Spencer, 1994). The six-stage procedure used was: (1) transcription and familiarisation of the entire data set; (2) coding; (3) developing a working analytical framework; (4) applying the framework; (5) charting data into the framework, and (6) interpretation and mapping of the data (Appendix 6) (Gale et al., 2013). Familiarisation of the focus groups was accomplished by listening to the recordings and reading the transcriptions several times. A deductive methodology was used to interpret and analyse the raw interview data. Coding was performed at this stage by adding notes alongside the transcription. Notes were then used to generate a set of codes, each with a brief description, which formed the primary analytical framework. The framework was then applied to each transcript which was methodically coded and relevant text being attached to the corresponding code. Following synthesis of the analytical framework, data was then outlined in a matrix created in Microsoft Excel. Themes and sub-themes were then generated after analysing the matrix and connecting codes which were grouped into structured topics. These topics were generated based on the main aims of the study and specifically generated themes and sub-themes from the data. Several charts for each focus group were generated on Microsoft PowerPoint to summarise the data.

Trustworthiness & Rigour

The researcher was embedded into the football club as a physical performance coach to the first team and academy as part of the research project. Thus, to mitigate potential researcher bias, the main researcher was challenged and critiqued by fellow researchers/supervisors at each stage of the data collection and analysis and subsequent framework development. To address trustworthiness and rigour, several criteria were highlighted based on their appropriateness for the research design. Subsequently, significant credibility, contribution and transparency were integrated into the research project and design (Smith & McGannon, 2018). This was achieved by (a) conducting worthy research in a topic/area of current literature that provides both a significant theoretical and practical contribution to the football club; (b) consulting the research team at each stage of data collection and analysis processes; (c) the use of member reflections to ensure credibility; and (d) highlighting key implications of the findings as well as transparency around the methodological process and challenges which ensued.

Results

Fitness Testing Data

Reliability

Table 1 shows between-session reliability data for the battery of physical fitness tests at each chronological age group. The CMJ proved to be a reliable measure across the whole sample of players included in this study (ICC = 0.97; CV = 3.4%). The strongest reliability for the CMJ was observed for the U16 group (ICC = 0.98; CV = 1.9%; ES = 0.1) whereas the U15 group had the weakest reliability (ICC= 0.82; CV = 4.8%; ES = 0.1. The eccentric braking strength test showed moderate reliability measures across the entire sample (ICC = 0.78; CV = 7.6%). The strongest reliability was observed for the U14 group (ICC = 0.93; CV = 4.1%, ES = 0.6), while the weakest reliability was observed in the U13 age group (ICC = 0.32; CV = 8.8; ES = 0.1). The drop jump test proved to be reliable across the whole sample of players (ICC = 0.92; CV = 7.6%), however the CV results reported are being above 5% show moderate reliability. The strongest reliability was observed in the U18 group (ICC = 0.95; CV = 3.6%; ES = 0.3), whereas the U16 group had the weakest reliability measures (ICC = 0.61; CV = 8.6%; ES = 0.5).

The isometric hamstring strength test proved to be a reliable measure across the entire sample of players for both left (ICC= 0.95; CV = 6.6%; $p < .05$) and right limb (ICC = 0.95; CV = 5.9%). The strongest reliability was observed in the U18 group (ICC = 0.93; CV = 3.2%; ES = .02), and the weakest reliability was seen in the U15 group (ICC = 0.80; CV = 9.0%; ES = 0.1) both in the left limb. When measuring hamstring strength relative to body mass the test showed moderate reliability across the whole sample (ICC = 0.79; CV = 6.6). The strongest reliability was observed in the U13 group (ICC = 0.94; CV = 3.6%; ES = 0) and the weakest reliability was shown in the u15 group ICC = 0.63; CV = 10.4%; ES = 0.2).

The Flying 20m sprint demonstrated excellent reliability across the whole sample of players (ICC = 0.95; CV = 2.0%). The strongest reliability measures were observed in the U16 group (ICC = 0.95; CV = 0.9%; ES = 0.1), while the weakest reliability was observed in the U18 group (ICC = 0.48; CV = 2.0%; ES = 0.5). Lastly, the 1000m time trial proved to be reliable across the entire sample of players (ICC = 0.93; CV = 1.6). The strongest reliability was observed in the U13 group (ICC = 0.93; CV = 1.2%; ES = 0.1), whereas the weakest reliability was observed in the U18 group (ICC = 0.74; CV = 2.2%; ES = 0.3).

Table 1. Between day test-retest reliability of physical fitness tests across age groups U13 – U18.

		U13 (n=11)	U14 (n=13)	U15 (n=13)	U16 (n=10)	U18 (n=12)
Countermovement Jump	Trial 1 (x ± SD) [cm]	27.1 ± 3.4	29.5 ± 3.8	33.2 ± 3.2	40.0 ± 5.2	41.3 ± 4.9
	Trial 2 (x ± SD) [cm]	26.9 ± 3.1	29.1 ± 3.2	32.7 ± 4.2	40.3 ± 5.3	40.4 ± 4.9
	ICC (CI)	0.96 (0.90-0.99)	0.92 (0.80-0.97)	0.82 (0.59-0.93)	0.98 (0.93-1.00)	0.93 (0.81-0.97)
	CV (%)	2.3	3.5	4.8	1.9	3.0
	ES	0.1	0.1	0.1	0.1	0.2
Eccentric Braking Strength	Trial 1 (x ± SD) [W.kg]	7.13 ± 0.83	6.66 ± 0.98	6.97 ± 0.98	8.12 ± 1.33	8.39 ± 1.26
	Trial 2 (x ± SD) [W.kg]	7.03 ± 0.69	6.60 ± 1.01	6.72 ± 1.10	8.42 ± 0.94	7.85 ± 1.10
	ICC (CI)	0.32 (-0.20 -0.70)	0.93 (0.82-0.97)	0.75 (0.46-0.90)	0.81 (0.50-0.94)	0.59 (0.19-0.83)
	CV (%)	8.8	4.1	7.5	5.8	8.8
	ES	0.1	0.6	0.2	0.3	0.5
Drop Jump	Trial 1 (x ± SD) [m/s]	1.29 ± 0.49	1.43 ± 0.25	1.48 ± 0.35	2.04 ± 0.30	2.20 ± 0.53
	Trial 2 (x ± SD) [m/s]	1.21 ± 0.38	1.45 ± 0.29	1.34 ± 0.34	1.91 ± 0.28	2.06 ± 0.54
	ICC (CI)	0.88 (0.69-0.96)	0.79 (0.53-0.92)	0.83 (0.41-0.94)	0.61 (0.14-0.86)	0.95 (0.55-0.99)
	CV (%)	12.0	8.5	7.8	8.6	3.6
	ES	0.2	0.1	0.4	0.5	0.3
Isometric Hamstring Strength Left	Trial 1 (x ± SD) [N]	217 ± 51	245 ± 55	279 ± 55	353 ± 65	393 ± 50
	Trial 2 (x ± SD) [N]	212 ± 50	250 ± 42	287 ± 59	354 ± 71	394 ± 46
	ICC (CI)	0.93 (0.81-0.98)	0.87 (0.69-0.95)	0.80 (0.56-0.92)	0.87 (0.63-0.96)	0.93 (0.83-0.98)
	CV (%)	6.4	7.3	9.0	7.0	3.2
	ES	0.1	0.1	0.1	0.0	0.0
Isometric Hamstring Strength Right	Trial 1 (x ± SD) [N]	215 ± 44	243 ± 52	292 ± 50	356 ± 49	378 ± 48
	Trial 2 (x ± SD) [N]	221 ± 48	254 ± 46	288 ± 58	360 ± 52	385 ± 44
	ICC (CI)	0.93 (0.80-0.97)	0.82 (0.58-0.93)	0.91 (0.77-0.96)	0.83 (0.55-0.95)	0.89 (0.74-0.96)
	CV (%)	5.7	8.3	5.8	5.8	4.0
	ES	0.1	0.2	0.1	0.1	0.2
Isometric Hamstring Strength (Relative)	Trial 1 (x ± SD) [N.kg]	10.1 ± 1.6	9.5 ± 1.1	9.9 ± 1.8	10.9 ± 1.4	11.2 ± 1.2
	Trial 2 (x ± SD) [N.kg]	10.1 ± 1.4	9.8 ± 1.3	9.5 ± 1.5	10.7 ± 1.5	11.3 ± 1.0
	ICC (CI)	0.94 (0.84-0.98)	0.66 (0.31-0.86)	0.63 (0.25-0.84)	0.76 (0.38-0.92)	0.90 (0.76-0.96)
	CV (%)	3.6	7.2	10.4	6.6	3.0
	ES	0.0	0.2	0.2	0.1	0.1
Flying 20m Sprint	Trial 1 (x ± SD) [m/s]	7.35 ± 0.43	7.30 ± 0.35	7.85 ± 0.57	8.53 ± 0.35	8.86 ± 0.28
	Trial 2 (x ± SD) [m/s]	7.45 ± 0.40	7.40 ± 0.45	8.09 ± 0.56	8.48 ± 0.37	8.74 ± 0.21
	ICC (CI)	0.91 (0.72-0.97)	0.90 (0.70-0.97)	0.83 (0.37-0.95)	0.95 (0.85-0.98)	0.48 (-0.03-0.81)
	CV (%)	1.5	1.6	2.2	0.9	2.0
	ES	0.2	2.6	0.4	0.1	0.5
1000m Time Trial	Trial 1 (x ± SD) [s]	221 ± 9	218 ± 11	225 ± 10	215 ± 5	201 ± 10
	Trial 2 (x ± SD) [s]	220 ± 10	222 ± 12	222 ± 10	216 ± 7	198 ± 7
	ICC (CI)	0.93 (0.81-0.98)	0.90 (0.26-0.98)	0.91 (0.36-0.98)	0.85 (0.61-0.95)	0.74 (0.35-0.91)
	CV (%)	1.2	1.0	0.9	1.1	2.2
	ES	0.1	0.3	0.3	0.2	0.3

n = sample size; x ± SD = mean ± standard deviation; ICC = intra-class correlation, all p< .05; CI = confidence interval; CV = coefficient of variation; ES = effect size

Chronological Age Validity

Table 2 presents construct validity of the physical fitness tests across chronological age groups. The CMJ demonstrated that significant differences were observed between all age groups apart from between U13 and U14 and between U16 and U18. Eccentric braking strength was only able to demonstrate significant differences between 14 and U16 and U18, and also between U15 and U16 and U18. The DJ demonstrated that reactive strength performance was significantly higher for U16 and U18 compared to U14 and U15. There was a significant difference of hamstring strength for both left and right limb between U13 and U15, U16 and U18 and also between U14 and U16 and U18. There was a significant difference between U14 and U15 for right limb strength, however no difference for the left limb. There were no significant differences across any of the age groups when assessing hamstring strength relative to body mass. The U15, U16 and U18 age groups all demonstrated significantly higher flying 20m max sprint velocity than U13. Similarly, greater max velocity was reported for the U15, U16, and U18 compared to U14. The time to complete the 1000m time trial was significantly less for the U18 compared to the U13, however there was no significant difference between the U13 and any other age group. U16 and U18 also demonstrated significantly better times to completion than the U14 and U15.

Table 2. Construct validity of physical fitness characteristics across chronological age groups U13 – U18.

		U13	U14	U15	U16	U18
Countermovement Jump [cm]	U13		0.82	4.95*	9.41**	10.90**
	U14			4.13*	8.59**	10.08**
	U15				4.45*	5.95*
	U16					1.49
Eccentric Braking Strength [W.kg]	U13		-0.33	-0.39	1.06	0.95
	U14			-0.06	1.39*	1.28*
	U15				1.45*	1.33*
	U16					-0.11
Drop Jump Reactive Strength Index [m/s]	U13		0.12	0.13	0.79**	0.97**
	U14			0.01	0.67*	0.86**
	U15				0.66*	0.84**
	U16					0.18
Isometric Hamstring Strength Left [N]	U13		16.20	69.00*	115.00**	127.40**
	U14			52.800	98.80**	111.20**
	U15				46.00	58.40
	U16					12.40
Isometric Hamstring Strength Right [N]	U13		-0.44	72.72*	114.53**	133.78**
	U14			73.16*	114.97**	134.22**
	U15				41.81	61.06
	U16					19.26
Isometric Hamstring Strength (Relative) [N.kg]	U13		-0.62	-0.10	0.77	0.77
	U14			0.52	1.27	1.39
	U15				0.76	0.87
	U16					0.12
Flying 20m Sprint [m/s]	U13		0.28	0.98**	1.19**	1.57**
	U14			0.70*	0.91**	1.29**
	U15				0.21	0.59
	U16					0.38
1000m Time Trial [s]	U13		1.99	1.21	-11.32	-24.21**
	U14			-0.79	-13.32*	-26.21**
	U15				-12.53*	-25.42**
	U16					-12.89

cm= centimetres; W.kg = watts per kilogram of body mass; m/s = metre per second; N = newtons; N.kg = newtons per kilogram of body mass; s = seconds * = <0.05, ** = <0.001

Growth and Maturation Validity

Table 3 presents construct validity of physical fitness test performance by maturity status. The CMJ demonstrated that the jump performance was significantly higher for the post-PHV group compared to both the pre-PHV and circa-PHV group however there was no significant difference between pre-PHV and circa-PHV. The only significant difference in eccentric braking strength was demonstrated by the post-PHV group who exhibited greater braking strength than the circa-PHV group. The DJ demonstrated that reactive strength was significantly greater for the post-PHV group compared to the pre-PHV and circa-PHV group. The post-PHV group revealed significantly greater hamstring strength than pre-PHV and circa-PHV in both left and right limb. Additionally, there was no significant differences between any of the maturity status groups when assessing hamstring strength relative to body mass. The Flying 20m sprint illustrated that max velocity was significantly greater for the post-PHV group compared to pre-PHV and circa-PHV group. The post-PHV group demonstrated significantly better 1000m time trial times than both the pre-PHV and circa-PHV group.

Table 3. Construct validity of physical fitness tests across maturity status.

		PRE	CIRCA	POST
Countermovement Jump [cm]	Pre		2.55	8.32**
	Circa			5.78**
Eccentric Braking Strength [W.kg]	Pre		-0.44	0.53
	Circa			0.97*
Drop Jump Reactive Strength Index [m/s]	Pre		0.04	0.47*
	Circa			0.42*
Isometric Hamstring Strength Left [N]	Pre		38.70	110.60**
	Circa			71.90**
Isometric Hamstring Strength Right [N]	Pre		29.20	113.20**
	Circa			84.00**
Isometric Hamstring Strength (Relative) [N.kg]	Pre		-0.26	0.53
	Circa			0.79
Flying 20m Sprint [m/s]	Pre		0.41	1.12**
	Circa			0.71**
1000m Time Trial [s]	Pre		-1.73	-13.56*
	Circa			-11.82*

Pre = Pre-Peak Height Velocity; Circa = Circa Peak Height Velocity; Post = Post Peak Height Velocity; * = <0.05, ** = <0.001

Sensitivity

Table 4 provides intra-player sensitivity analysis of the physical fitness testing battery between two time points which were 12 months (one-season) apart. The CMJ was able to detect significant performance changes for all age groups apart from the U13 players. The eccentric braking strength test was able to detect significant performance changes for all age groups. The DJ exhibited was able to detect significant performance changes for the U14, U16 and U18 groups of players. The isometric hamstring strength test was able to detect significant performance changes for U14 and U16 for both left and right limb. Only the U16 group observed significant changes when assessing hamstring strength relative to body mass. The flying 20m sprint was able to detect significant performance changes for U13, U16 and U18 groups of players. The 1000m time trial test was able to detect significant performance changes for U13, U14, U15 and U16 groups of players.

Table 4. Sensitivity analysis of physical fitness tests across age groups U13 – U18.

		U13 n = 8	U14 n = 10	U15 n = 11	U16 n = 10	U18 n = 6
Countermovement Jump	Start of season 1 (x ± SD) [cm]	24.9 ± 2.5	24.4 ± 3.2	28.6 ± 3.8	33.0 ± 4.9	35.2 ± 3.5
	Start of season 2 (x ± SD) [cm]	26.8 ± 3.7	29.7 ± 4.4	33.0 ± 3.5	38.9 ± 6.0	38.9 ± 3.8
	p	0.14	0.001	<0.001	<0.001	0.025
	ES (*d*)	0.6	1.4	2.0	2.8	1.3
Eccentric Braking Strength	Start of season 1 (x ± SD) [w.kg]	5.60 ± 1.11	5.63 ± 0.68	5.05 ± 0.6	6.65 ± 1.29	5.80 ± 1.16
	Start of season 2 (x ± SD) [w.kg]	7.35 ± 0.92	6.76 ± 1.11	6.93 ± 1.03	8.01 ± 1.3	7.87 ± 1.4
	p	0.03	0.011	<0.001	0.007	0.015
	ES (*d*)	1.8	1.1	1.9	1.4	2.1
Drop Jump (Reactive Strength Index)	Start of season 1 (x ± SD) [m/s]	1.02 ± 0.54	1.01 ± 0.25	1.08 ± 0.23	1.55 ± 0.10	1.88 ± 0.67
	Start of season 2 (x ± SD) [m/s]	1.33 ± 0.57	1.48 ± 0.21	1.50 ± 0.36	2.03 ± 0.28	2.29 ± 0.63
	p	0.17	<0.001	<0.001	<0.001	0.001
	ES (*d*)	0.6	1.7	1.4	1.8	2.6
Isometric Hamstring Strength Left	Start of season 1 (x ± SD) [N]	185 ± 21	193 ± 36	276 ± 69	270 ± 51	327 ± 70
	Start of season 2 (x ± SD) [N]	212 ± 42	237 ± 48	293 ± 57	342 ± 70	377 ± 29
	p	0.073	0.017	0.323	<0.001	0.071
	ES (*d*)	0.8	0.9	0.4	1.6	0.9
Isometric Hamstring Strength Right	Start of season 1 (x ± SD) [N]	198 ± 29	210 ± 44	285 ± 58	259 ± 40	340 ± 82
	Start of season 2 (x ± SD) [N]	205 ± 35	231 ± 46	305 ± 43	343 ± 62	371 ± 46
	p	0.5	0.024	0.43	0.005	0.298
	ES (*d*)	0.3	0.9	0.3	1.2	0.5
Isometric Hamstring Strength (Relative)	Start of season 1 (x ± SD) [N]	10.4 ± 1.3	9.2 ± 1.4	10.2 ± 1.1	9.3 ± 1.5	10.2 ± 2.1
	Start of season 2 (x ± SD) [N]	10.3 ± 1.7	9.4 ± 0.9	10.4 ± 1.8	10.8 ± 1.4	11.2 ± 1.4
	p	0.82	0.527	0.8	0.021	0.192
	ES (*d*)	0.1	0.2	0.1	0.9	0.6
Flying 20m Sprint	Start of season 1 (x ± SD) [m/s]	7.03 ± 0.35	7.16 ± 0.3	7.66 ± 0.56	7.75 ± 0.36	8.34 ± 0.23
	Start of season 2 (x ± SD) [m/s]	7.22 ± 0.42	7.34 ± 0.31	8.03 ± 0.64	8.53 ± 0.39	8.9 ± 0.29
	p	0.03	0.087	0.102	<0.001	0.018
	ES (*d*)	1.0	0.7	0.6	3.3	1.7
1000m Time Trial	Start of season 1 (x ± SD) [s]	238 ± 15.81	230 ± 5.93	234 ± 9.43	228 ± 12.32	207 ± 8.66
	Start of season 2 (x ± SD) [s]	222 ± 8.87	217 ± 8.72	219 ± 10.16	214 ± 3.96	200 ± 6.02
	p	0.01	0.002	0.002	0.002	0.088
	ES (*d*)	1.4	1.5	1.9	1.5	0.9

n = sample size; x ± SD = mean ± standard deviation; *p* = significance; ES = effect size;

Focus Group Data

Analysis of individual focus groups with physical performance coaches and technical coaches, independently, resulted in the development of a specific framework based on perceptions and thoughts around physical fitness testing within the academy structure by these key stakeholders.

Analysis of the raw data gathered from the focus groups was generated into codes and notes to form primary impressions of the data. Forty-four initial codes were noted for the physical performance focus group. Following this stage, initial concepts were established and then grouped to determine a framework which addressed the main aims of the study. Thirteen codes were grouped into the theme Player Development; thirteen codes were grouped into the theme surrounding Testing of the physical fitness tests; and eighteen codes were grouped into the theme Reporting. Fifty-seven initial codes were noted for the technical coaches focus group. Similar to the physical performance coaches, the responses from the technical coaches allowed for the three main themes to be consistent across both focus groups. Twenty-eight codes were grouped into the theme Player Development; eighteen codes were grouped into the theme Testing; and eleven codes were grouped into the theme Reporting.

As mentioned, three important themes with multiple sub-themes were developed following analysis of the framework process. These themes were (i) Player Development (ii) Testing and Reporting as seen in table 5 below.

Table 5. Focus Group interviews first-themes, sub-themes and perceptions in relation to the physical fitness testing battery.

Theme 1 – Player Development	
Sub-theme	Perceptions
Physical Performance coaches - Enhancing physical capabilities	– Establish fundamental movement patterns and build capacities within these movements such as strength and power – Ensure academy players are involved in greater range of sports at a young age & educate parents on benefits – Reduce player's load during peak height growth and substitute with alternative training
Pathway through the academy	– Develop each age group at age specific rate with clear path of physical progression from U13 to first team – Progressive year to year improvements in development of player will provide greater chance of progressing from academy to 1st team level
Barriers for coaches	– Player to coach ratio limits one-to-one coaching time and opportunity with each age group.
Technical Coaches – Content	– Different goals at different stages throughout the academy dependant on age group – Development always trumps winning throughout the academy, although naturally players and coaches always want to win football matches. – Important training is enjoyable for them after long days at school.
Attributes important to coaches	– Talent is the main attribute coaches seek. Speed, endurance, strength and athleticism are important.
Essential psychological factors	– Good attitude, application and determination is essential – Ability to embrace challenges and mentally robust enough to overcome adversity
Intervention strategies	– Promote or regress players based on their biological maturation and physical profile to provide best development opportunities – Create a bit of competitiveness within the game related and conditioned games – Make each individual a better person as well as better footballer
Theme 2 - Testing	
Sub-theme	Perceptions
Physical Performance coaches – Rational for current testing battery	- Testing battery follows out-sourced English Football Association physical profile framework, with slight adaptations

	- In house physical profile of different tests with benchmarks for each test based on historical data collection - Proxy measures of speed, deceleration capabilities etc are used as they are quicker to gather and more pragmatic - Legitimate scientific rationale for tests chosen - Once you commit to the tests it's smart to stick with it as you gain more insight the larger your data set becomes
Content of the physical testing	- Got to be pragmatic and realise what is feasible and what you can logistically achieve - Pre-covid = 2-hour testing (>2 weeks). Unpopular with coaches. Less tactical & technical training - Testing now achieved in 45 minutes gathering good reliable data - If time resources weren't an issue: - Agility test, 0-30m speed test, Run specific Isometric Strength - Potential to detect prospects for future
Technology for data collection	- Investment from club in new VALDHub technology - ForceDecks, Force-Frame & Nordbord - Show that investment from club in new technology is worthwhile - Advancement of technology means one practitioner can now carry out full testing protocol
Technical Coaches – Assessment of testing procedure	- The testing is a benchmark for coaches to see where the players are currently at and in comparison to previous seasons - Understand importance of testing. Ticks all boxes from football point of view - Sometimes the good physical testing profile doesn't transfer on to the pitch. Some tests do.
Potential improvements	- Yo-Yo test as its more specific to football. 5-0-5 for change of direction assessment. 10-30m sprint for acceleration capabilities - Player's just doing specific tests for their position rather than all testing
How coaches use testing results	- Testing only used as a guide, coaches eye inform what player can or can't do on the pitch - Framework for coaches to use to see where a player is at physically - Allows coaches to reference physical testing results when having conversations with players/parent
Theme 3 – Reporting	
Sub-theme	Perception
Physical Performance coaches – Presentation of testing results	- Testing results sent as detailed and descriptive email highlighting both squads and individual's strengths & weaknesses - Report provides clear image specific to each squad and player's physical profile - Sports science aim to make the reports clear, easy to read and explain to players/parents

Outcome of the testing results	- Data is presented as fresh insight for coaches rather than a confirmation tool - Allows for planning and periodisation of programmes for each squad - Gauge efficacy of S&C programming to show players are progressing physically within season and also year to year - Creates collaboration between sports science and coaches - Allows feedback from technical coaches - Follow up on reports by having chats with coaches to discuss squads and individual players
Importance of growth and maturation	- Sports office used to log maturation measurements and create report - Reports can show players who are special physical prospects - Key indicator in report shows which stage of maturation each player is at through three categories: - Pre/Circa/Post Peak Height Velocity - Circa-PHV or large growth spurt individuals are flagged to make coaches and medical department aware that they may be more susceptible to injury during this stage - Sports science could provide presentation of maturation report to illustrate key points to coaches
Technical Coaches – Thoughts on presentation of reports	- Reporting could link more to football side of things - Sports science data can be too much and not clear enough - Simplified, easy to use and more clarity on reporting to make it easy for coaches to read (e.g. someone who is not a sports scientist) - Reporting to show previous testing scores for players to reference if improvements have been made or not - Include club wide specific benchmarks filtered from first team all the way down the academy
Education presentations for coaches	- Educate coaches on what they can do if the testing results are not good or where coaches want them to be to improve these physical measures - Presentation for all coaches to explain rationale for testing, how this translates to on pitch and being a beneficial gauge for football players

The focus group interview transcription allowed for the three main themes to be consistent between both the physical performance and technical coaching staff. This can demonstrate that the perceptions and interpretations of the physical fitness testing battery within the academy as a whole is thought of in a similar theme between the multidisciplinary teams. This shows a unified approach from the football club and illustrates that key stakeholders within the academy understand the key purposes of the physical fitness testing. This unified approach demonstrates that these two multidisciplinary teams are both working towards a strong philosophical ethos from the club regarding physical fitness testing within the academy, which is a positive sign for young players development.

Theme 1 – Player Development

The first theme that both focus groups aligned with was the importance of player development within the academy. Physical performance staff and technical coaching staff both agreed that for players to develop, different aims and goals for stages in relation to chronological age group progression is key.

> "The key with academy players is progressing them year to year, which involves developing each team at an age specific rate". Physical Performance Coach 2.
>
> "In terms of playing development, it's all very different depending upon the stages of which they are at. So, under 11 under 12 is all about touches and football. It's all about fun. It's all about players enjoying themselves. Then at 13's and 14s I think things change for them in a sports science way especially and a change of what they can do in the gym and in a football sense, it becomes more about development. At 15s and 16s it becomes more competitive, but it's more about refining the individual and making that individual a better player. And then after that, it becomes more competitive and teaching them how to win, if you like". Technical Coach 1.

However, from the main themes, these were then categorised into different sub-themes. This perhaps shows a difference in interpretation or focus of what is important within these topics to different people within multidisciplinary teams within the academy structure. The intricacies and requirements of the different roles within multidisciplinary teams within football academies can be a factor in different sub-themes within this study, with the physical performance and technical coaches wanting or requiring different information from these themes. Physical performance coaches highlighted that in order to develop players they must improve their physical capabilities through various movement patterns within a gym setting, encouraging individuals to participate in other sports while also vocalising barriers which they have to achieving this goal. Whereas technical coaches underlined the importance of certain physical and psychological attributes that they considered essential for individuals within the academy to possess in order to develop as a football player.

> "I think the main goal of working with academy kids first and foremost is establishing the basic fundamental movement patterns by which I mean squat, hinge, brace, push and pull". Physical Performance Coach 1

> "If you were to break down one-to-one coaching time with each player in that 30 minute it's quite small. So generally speaking, in academies it's quite a big player to coach ratio in the gym which limits time with each player". Physical Performance Coach 1

> "Talent is obviously the first thing you look for". "They must be athletic, the way the modern game is now that you have to be very, very athletic to play at the level of the we're looking for them to play at. Other than that, technically exceptional". Technical Coach 1

> "For me you can be the most technical, most gifted player, but you must have the attitude and application to match". Technical Coach 2

Theme 2 – Testing

Similarly to the first theme, the sub-themes were categorised into separate themes for both groups in regard to the testing within the academy. The physical performance coaches reported their focus and attention to be around the rationale for why they are including certain tests within the testing battery and the protocol for carrying out the testing in the most efficient way possible, while also working around the coaches' preferences in this regard. A main feature of the physical performance responses revolved around the technology used for testing. The practitioners highlighted that investment in greater quality and amount of technology allowed for simplified testing procedure and a greater range of measures that can be gathered from the technology. The responses suggests that the testing is a systematically calculated process from the physical performance department to get the most out of the technology that they have and the aim of completing this within the least time possible to suit all departments within the academy.

> "The Testing battery follows out-sourced English Football Association physical profile framework, with slight adaptations, which now results in an in-house physical profile of different tests with benchmarks for each test based on historical data collection" Physical Performance Coach 1.
>
> "Pre-covid testing was 2-hour protocol spread over 2 weeks which wasn't popular with coaches as it took time away from technical/tactical training. Proxy measures of speed, deceleration capabilities etc are now used as they are quicker to gather and more pragmatic, which now means we can test the whole squad in 45 minutes and get good reliable data" Physical Performance Coach 1.

The technical coaches reported that they understood the importance that physical fitness testing has regarding academy players, however illustrated that these results are only used as a guide to either provide confirmation to what they are seeing with a player on pitch or questioning why some players who are testing well physically are not showing these capabilities to movements on pitch. This suggests that technical coaches may already have a pre-determined opinion on individuals' physical fitness and that the testing results may only be used as a confirmation tool to corroborate what they already think about a player.

> "The testing is only a guide for us, and what we see out on the pitch is the main thing and usually our eyes tell us on the pitch what a player can do and what player can't do" Technical Coach 1.
>
> "I see it as a benchmark for me, it allows us to see the application of the players and also you get to see where they are physically compared to last season" Technical Coach 2.

> "It's a framework in which we go to as it gives us an indication of where they are, and it also allows us as coaches to reference these test results when having conversations with the players/parents" Technical Coach 1.

Congruently, both groups documented that if timing and resources were not an issue, then certain tests, such as agility and speed measures, would be beneficial to include in the testing battery to strengthen the overall physical testing battery. This suggests that both physical performance coaches and technical staff are aware of the importance that measures from fitness testing can provide and give context to individuals physical abilities in relation to what is expected to progress as a football player.

> "If we could measure them more directly so potentially a 5/10m acceleration test" Physical Performance Coach 2.

> "5-0-5 test that was one I liked. I think this would be a good one for goalkeepers, defenders seeing how quick they could change direction" Technical Coach 2.

Theme 3 – Reporting

Physical performance and technical coaching staff both agreed that reporting was a main theme in regard to the testing, however there was also a difference in the categories of the sub-themes for this section. The physical performance coaches reported the reasons for the way they present the reports, which in their eyes was to document the physical profile of each squad and individual player to highlight strengths and weaknesses while also making this clear and easy to read for technical coaches. Although, the technical coaches reported that they believe the reports could be improved to align more with the football side of things and they reports could be made simplified even more for coaches to read.

> "I think it could be made more in line with the football side of things and so making it more pertinent to what players doing a game, so explaining why they're doing that testing and when they use that in a game. Making it as simple as to understand this as possible, and easy to use as possible and with more clarity on it. And because I think a lot of the time a lot of sports science data we get is too much and not clear enough with enough clarity for us just to pick up, look, see what they get and then put down" Technical Coach 1.

This suggests that there is a difference in opinion between the two groups regarding the presentation of the reports and the amount of information the reports should entail, with the physical performance coaches having a more astute consideration for the testing technology and data that can be provided from it. The technical coaches reported that education of the reporting could be a key factor in creating greater collaboration with the physical performance department and also provide the technical coaching staff across the academy with a greater understanding of the rational and subsequent analysis of fitness testing results. This aligned with the physical performance staff who congruently reported that the reporting of the testing measures creates collaboration between the two departments while also allowing the technical coaches to provide feedback about the reports.

> ” We get the testing results, but then what do we do if those testing results aren't as good as what we want them to be, what can we do to make that player better, and what can that player be doing on a daily basis in the gym to make him better to improve the testing score? So really, we're just given a test result, but then not doing enough about it. I think we could do more”. Technical Coach 1.
>
> “It’s something they can feed back about their overall status of the squad and they are the ones that control 90% of the physical work that players do so it’s an opportunity for them to work on the weaknesses they might see but also we might have identified from the profiling through the drills they do on the pitch and in that sense its quite collaborative” Physical Performance Coach 2.

The physical performance coaches also documented the importance of growth and maturation reporting as a result of the measures gathered from testing. Physical coaches stated that reports include the stage of PHV each individual player is currently at during the time of testing, while also flagging any individual who is undergoing a large growth spurt. The technical coaches also highlighted the need for intervention strategies in regard to maturation status of individuals within the player development theme, illustrating that both departments are working together to ensure this is an essential focus throughout the academy.

Discussion

This study aimed to evaluate the reliability, validity, and sensitivity of a physical fitness testing battery employed across all age groups within a Scottish Premier League academy. This study also sought to explore the rationale and perceptions of the physical fitness testing battery from key stakeholders involved in the club's academy structure. Findings from this study suggest that most of the fitness tests used by the club were reliable demonstrating acceptable between-day reliability. Performance on the fitness tests only differentiated between chronological age groups when comparing distinctly older and younger ages (i.e. U13 vs. U18 groups) and maturity status (i.e. pre-PHV vs. post-PHV). The testing battery was also sensitive to detect performance changes after a one-year training period for most tests. However, findings were test-specific with some measures demonstrating unacceptable reliability for specific age groups and an inability for some tests to differentiate between consecutive age groups. Findings gathered from kay stakeholders illustrate that although there was a general consensus of the importance of physical fitness testing within the academy from key stakeholders within the two multidisciplinary teams, there was an incongruent interpretation regarding the current testing battery design and the presentation of results from these fitness tests.

Reliability

In accordance with previous research across similar age ranges, test re-test reliability was reported as good-excellent for most tests and across the entire sample of players (Hulse et al., 2013; Dugdale et al., 2019). However, when examining between-day reliability of the fitness tests included within this study, no clear trend was evident when evaluating test score consistency and age group. For example, eccentric braking strength reported unacceptable-moderate reliability for most age groups; notably U13 players. Due to the physical demand and role of muscular strength on eccentric strength capabilities (Spiteri et al., 2013), it is probable that players lack necessary physical qualities due to limited physical development as well as the association of younger players with early maturation within the current study, could result in the lower reliability in test performance (Paul & Nassis, 2015). Although in this study eccentric braking strength is gathered as a "proxy" measure during a CMJ, the findings are consistent with previous research which highlight lower reliability for COD measurements among young age groups (U11-U13) (Dugdale et al., 2019), which is also a determinant of eccentric braking strength capabilities during the deceleration action (Lloyd et al., 2013). Thus, with the lower levels of reliability reported for most age groups and moderate CV% (>5%), it may be suggested that this test is less suitable as a measurement to assess eccentric braking strength performance among youth soccer players.

Good to excellent reliability was observed for most age groups for the CMJ, DJ, flying 20m Sprint, and 1000m time trial. However, unacceptable reliability was reported for the flying 20m sprint in the U18 group, and moderate reliability for drop jump in the U16 group, respectively. The limited sample numbers in each of the age groups recruited for this study may explain these findings. The small sample size per age group may affect the statistical power or meaningful precision required to obtain reliable results (Hopkins, 2017; Hecksteden, Kellner & Donath, 2022). Within soccer studies participant numbers can be limited, therefore, the low numbers within each age group within the current study may have a substantial effect on reliability of these tests, with one or two outliers (high performing or low performing) in a testing session potentially increasing the variability within that group and thus increasing the probability of error (Springate, 2012). Moderate reliability was reported for the isometric hamstring strength test, when reported relative to body mass across three age groups (U14, U15, and U16). These results reiterate the notion that there was no clear trend for between-day reliability across tests or age groups. The reliability of the testing battery may also be affected by growth and maturation. A wealth of research on the effects of growth and maturation on physical performance characteristics within youth soccer players exists (Towlson et al., 2021; Parr et al., 2020; Cumming et al., 2019). Within the present study, there were many participants around the time of (circa) PHV. These individuals may have been experiencing advancements in their physical abilities or may also have been experiencing a disruption in motor coordination – typically referred to as "adolescent awkwardness" – in relation to their increased growth, thus impacting the consistency of their test performance (Johnson et al., 2022).

Validity

The testing battery was unable to differentiate between all chronological age groups, with clear differences being reported between the upper and lower spectrum of age groups for most tests (e.g., U18/U16 vs. U13) and no differences being illustrated between consecutive age groups (i.e., U13 vs. U14, or U16 vs. U18) for all tests. This finding is consistent with previous research whereby performance differences were observed when comparing younger and older (i.e., U11-U13 vs. U16/U17) youth soccer players, but not necessarily between consecutive age groups (Dugdale et al., 2019). It is well-established that age-related physical performance, anthropometry, and morphology increase significantly with age (Williams, Oliver & Faulkner, 2011; Parpa and Michaelides, 2022). Further, it is well documented that individuals post-PHV are typically stronger, faster, and more powerful than their less mature or pre-PHV peers (Johnson, Farooq & Whiteley, 2017). Research by Parr et al. (2020) reports that stage of maturity was documented as a significant and clear predictor of performance in the CMJ, COD test and 5m and 20m sprint tests. Congruently, in this study, maturity status had a significant effect on physical performance measures with post-PHV participants reporting significantly greater performance in all tests in comparison to pre- and circa-PHV, except for measures of eccentric braking and relative isometric hamstring strength. These findings show that players with advanced maturity status (i.e. post-PHV) will likely possess a significant advantage in relation to their physical performance across a range of fitness tests.

The inability of a number of fitness tests included within this study to differentiate between chronological age groups is of applied importance. Previous findings suggest that the onset of the adolescent growth spurt (i.e., PHV) is individual in timing and tempo (Malina et al., 2015) and the commencement and cessation of PHV typically occurs between 10.7 – 15.2 years of age (Towlson et al., 2018). These timings, combined with the range of ages and stages of maturity within the sample of the present study may suggest why no differences in test performance were observed between adjacent age groups. Considering that chronological age and biological maturity rarely progress at the same rate (Vaeyans et al., 2006), there are likely to be markedly differences in the inter-individual maturation 'journeys' within each chronological age group of this study. Comparable research suggests that variations of five to six years difference in biological age may be prevalent among chronological age groups in soccer (Towlson et al., 2021). As such, it is likely that the participants from U13-U15 age groups – the groups displaying no differences in between-group test performance for several measures within this study – are at varying stages of maturation and groups could be considered synonymous to each other. The implication of this finding illustrates that coaches and practitioners should interpret results with caution when comparing results between adjacent age groups and when referencing normative data.

Sensitivity

In this study, the testing battery was sensitive enough to detect significant performance changes over a one-year period. However, this was again dependant on both the test and age group. The U16 group were the only group to report significant changes in performance across a one-year period for all the physical fitness tests. The CMJ, eccentric braking strength, drop jump, and 1000m time trial reported significant changes in performance across all age groups with the exception of the eccentric braking strength test and drop jump within the U13 group, and the 1000m time trial for the U18 group.

Previous research has debated as to whether field-based fitness tests may be sensitive enough to distinguish within an already selected homogenous group of youth soccer players (Buchheit et al., 2011, Bergkamp et al., 2019). Within the current study, it is possible that learning effects may have occurred as players repeatedly perform the tests within the fitness testing battery (Paul & Nassis, 2015). Between the two testing sessions reported during the one-year period, participants completed 3 testing sessions, having gained an increased familiarity with the task of each test, thus potentially may improve their technique or approach to the test (Burgess and Naughton, 2010; Hewit, Cronin & Hume, 2013). Similarly, differences in test performance over this time could be due to the training effect that participants have undergone. Although it is unclear if these improvements will have materialized from physical or skill components (i.e., technical qualities), progressions in chronological and biological age are also likely to have influenced performance on the testing battery. Within the current study it is clear that there are similarities regarding the reliability, validity and sensitivity of the testing battery. Although all three factors have been discussed individually, these factors are all likely somewhat linked. It is evident that reliability, validity and sensitivity of the testing battery is very much test specific and dependant on age bracket or maturity status. As discussed, there are several factors that may influence this such as study sample size and familiarity of each test, however the main influential factor is likely to be the growth and maturation status of the academy players involved within the current study (Parr et al., 2020; Towlson et al., 2022). It is therefore important for key stakeholders within the academy to take these factors into consideration when interpreting the fitness testing results, especially within TI and TD processes within the club and the selection/de-selection of academy players and future prospects.

Stakeholder perceptions

The focus group interviews conducted with key stakeholders involved within the academy provided an insight to the rationale and perceptions of the physical fitness testing battery currently utilized for the U13-U18 youth soccer players. The analysis resulted in the development of a framework, which established three main themes related to the testing and monitoring practices in the academy: 1) Player Development, 2) Testing, and 3) Reporting. Theming of the responses was consistent between both the physical performance staff and the technical coaching staff, resulting in identical first-order themes. This finding illustrates congruency in perceptions and understanding of the role of the physical fitness testing between the two groups and shows a united and cooperative approach to player development, as proposed in talent development environments (Tee & Rongen, 2020). Recent research has suggested structures and methods to efficiently integrate multidisciplinary practitioners within high performance support departments (Sporer & Windt, 2017). This is an important and positive factor for player development as, without a supportive and consolidated environment in place, the capacity for football academies to produce elite level soccer players may be limited (Burgess & Naughton, 2010; Ivarsson et al., 2015). Previous research has also proposed that multi-disciplinary teams are inclined to operate best when all staff members are working towards mutually agreed, definitive and shared goals (Reid, Stewart & Thorne, 2004; Roncalglia, 2016). The multidisciplinary teams in this study demonstrated that they are both working towards unified principles in line with the football club's ethos regarding player development, which is established by both groups identifying identical first-order themes, illustrating that practitioners may be working in agreement within a favourable operating working environment.

Although the three first-order themes were consistent for both groups, differences were observed between groups when categorising lower-order themes. This highlights that although different departments within academy settings may be working towards the same overall goal, there may be differences in approaches, perceptions, or priorities of certain aspects of player development that may be more important within each stakeholder group (McGuigan et al., 2023). The complexities and demands placed on different roles within player development in academies may lead to practitioners desiring and prioritising different information from fitness testing practices within the academy.

Both physical performance and technical staff reported "Player Development" as a first-order theme within the focus groups. Both groups had similar responses within this theme, adopting an individual approach to developing players considering the impact of chronological, training, and biological age on their development. Similarly, both groups highlighted key physical and physiological qualities that are required to progress successfully throughout the academy and integration with the development and first team training environments. Previous research reinforces this perception stating that youth players with enhanced physical capabilities have a greater likelihood of progression to first team football (Dodd & Newans, 2018). As mentioned within the introduction of this thesis, physical demands during both training and match-play have increased across the last decade, with players carrying out greater high-intensity running and sprint distance (Barnes et al., 2014). This has likely influenced the importance of physical attributes, such as aerobic endurance and maximal sprinting speed, being recognised as discerning factors between successful and unsuccessful elite youth soccer players (Ade, Fitzpatrick & Bradley, 2016). Therefore, it is unsurprising that both groups of key stakeholders stated the importance of these attributes as key factors of player development within the academy.

The second theme identified by coaches and physical performance staff related to the physical fitness testing procedure itself. This is where sub-themes between the physical and technical coaches differed. Physical performance coaches identified that the rationale and content of the testing battery was derived from a scientific framework (i.e., EPPP, 2015; Ford et al., 2020), that is now incorporated from the first team through all academy age groups. Responses also highlighted the investment in technology from the club which allows for a more time-efficient and pragmatic approach to testing and monitoring. Physical performance staff perceived fitness testing as an important tool to monitor and evaluate physical performance of individual players and chronological age groups (Weston, 2018). Conversely, technical coaches articulated the translation of testing results that they receive to technical, on-pitch performance, as well as identifying potential improvements they thought could further develop the testing battery related to technical and tactical player development (Cripps, Hopper & Joyce, 2016; Dugdale et al., 2020; Alcântara et al., 2023). A reiterative response from technical coaches was that physical testing results are only used as a guide, citing that the coach's eye can inform decisions on player development on the pitch including factors that may not be explicitly assessed within the fitness testing battery (Christensen, 2009; Jokuschies, Gut & Conzelmann, 2017; Lath et al., 2021). Research has documented four main characteristics that can be identified from the coach's eye, which was defined as intuitive, subjective, experience-based, and holistic (Lath et al., 2021). This approach is typically a dominant contributor to the overall decision-making procedure of talent selection/de-selection in soccer (Roberts et al., 2019). Previous research also documents similar findings where the importance of fitness testing in academies is perceived as important by both strength and conditioning and coaches in rugby. However, greater variability in importance is observed by coaches who identify pitch-based performance as being more informative for team selection and career progression (McCormack et al., 2020). This illustrates the difference in interpretation of the importance of the measures gathered from the physical fitness testing battery between the two groups. Within the present study, the two multidisciplinary departments should ensure that practitioners are aware and have a good understanding of each department's perceptions of the physical fitness testing, physical qualities and challenges faced. Following this, both departments should work in harmony to help minimise the differing opinions by working together and potentially developing a performance framework together to accomplish productive integration from all stakeholders involved within the academy (Richards, Collins & Mascarenhas, 2012; Tee & Rongen, 2021).

Lastly, physical performance staff perceived the systematic planning and implementation of the fitness testing battery as positive and influential to their position within the academy, demonstrating an astute consideration for the testing processes, technology, and data gathered (Bishop, 2008). Technical coaches, however, reported that fitness testing measures may mostly be used as a confirmation tool to corroborate what they are observing on pitch and during analysis of individual players. These between-stakeholder dissimilarities illustrate some of the difficulties that stakeholders from different departments may face regarding players development (Reid, Stewart & Thorne, 2022; Tee & Rongen 2020). To ensure a more collaborative recognition of the fitness testing battery and an appropriate understanding of the useful information it can provide, it may be beneficial for the physical performance department to provide a presentation session illustrating why each test is chosen as a measurement and how these tests will contribute to a player's physical performance on pitch. Drawing in video analysis of player's executing the movements that are associated with the testing battery may result in coaches being more receptive to the usefulness of each test.

The final theme identified by both groups revolved around the reporting of the fitness testing results. Physical performance coaches documented that detailed reports were provided to highlight strengths and weaknesses of each individual player's physical profile, while aiming to do so in a clear, simple, and contextual way for the technical coaches (McCormack et al., 2020). Physical performance staff would also use testing results to gauge the efficacy of the strength and conditioning programmes, and plan and periodise these programmes for each squad within- and between-seasons. However, technical coaches illustrated that they believed the reports could be simplified even more for *"someone who is not a sports scientist"*, while also better linking the reports to how this contextually translates onto the pitch. This illustrates a difference of opinion when it comes to the presentation and content of the reports within the academy. Technical coaches and physical performance coaches should look to create a clear dialogue of communication at the start of every season, and possibly after each quarterly scheduled testing session, to ensure the presentation of the testing reports is providing easy to read, informative and meaningful information for both departments (Gregson et al., 2022; Rothwell et al., 2020).

Physical performance coaches also showed a more discerning bias towards data analysis when reporting the fitness testing measures, whereas technical coaching staff seem to hold a more negative view of "data", and instead wished for guidance from reports to articulate how the data translates to areas for player physical development on the pitch. Communication between coaches and practitioners in this final theme emerged as an important factor. Previous research has demonstrated that effective communication systems are vital for multidisciplinary function, which would involve multidisciplinary teams requiring a clear understanding of the information which has to be shared, by whom, and the time frame in which it should be shared within (Roncalglia, 2016). This highlights an area within the multidisciplinary team which could be improved in future, with regular discussions between key stakeholders and practitioners within the academy being deemed a beneficial addition to the operational structure and planning procedures currently in place. These regular discussions will allow practitioners within the multidisciplinary team to openly and safely communicate their thoughts and ideas between stakeholders, which can, in turn, contribute to the development of successful interpersonal relationships (Fleissig, 2006), expanding innovative performance (Kessel, Kratzer & Schultz, 2012) and engaging personnel with performance improvement and team education (Rathert, Ishqaidef & May, 2009).

Limitations

A limitation of the current study was the number of participants recruited within each age group. As this study adopted a single-club case study design, the number of players eligible to participate was limited due to this factor. Typically, the academy has a total number of 154 players signed to the academy which ranges from 9 – 18 years of age across a span of nine age brackets (U10's to U18s). Further, players may sustain injuries or illness preventing them from completing the multiple testing sessions adopted within the present study. Academy football may also experience high player turnover due to selection/deselection and drop out (Ford et al., 2020). Therefore, the mean number of participants who completed the testing sessions one and two was twelve per chronological age group, whereas this number was reduced to nine for players completing all three testing sessions. A soccer team typically consists of 15 – 20 players, therefore, research within these populations typically operates within small sample sizes (Hopkins et al., 2001). While this research aligns to sample numbers of studies adopting comparable designs (Buchheit et al., 2010; Deprez et al., 2015; Di Mascio 2020), an increased sample size for each chronological age group may have a meaningful influence on the results. Additionally, as mentioned previously the validity of GPS devices for measuring maximal sprinting has been questioned by researchers due to typical errors associated with collecting data at higher speed thresholds (McLaren et al., 2016). Similarly, the associated error in measuring the maturity status of youth athletes using the Khamis-Roche method should be taken into consideration by practitioners, therefore the accuracy and conformity of this data is of significant importance if soccer academies are to use this method to categorise their player's and inform their long-term physical development. This study also represents stakeholders from one professional soccer academy within the Scottish Premier League and, as such, the feasibility for concluding and generalising the findings may be limited. Conducting research in several professional soccer academies, not only in Scotland, but in the UK as a whole, may provide findings more representative to this demographic as a whole.

Conclusion

These findings emphasise that coaches and practitioners should interpret fitness testing results with caution when comparing results to chronological age specific normative data, specifically taking into account each individuals growth and maturation status at the time of testing. It should be considered that fitness testing is only a mechanism which can help with the design and prescription of training, however, player selection/de-selection should be formed using a holistic approach which includes a number of factors such as technical and tactical skills, physiological and psychological qualities (Paul & Nassis, 2015). The current study also presented a novel framework of the interpretation and rationale of the fitness testing battery from the key stakeholders involved in the academy structure. The findings shows that stakeholders within the soccer club understood the importance of fitness testing for player development and progression through the academy, however, practitioners from different multidisciplinary teams within the academy had different views of interpretating findings from the fitness testing battery and reporting of these results.

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Appendices

Appendix 1) Participant and Parent/Guardian Information Sheet

What is the study about?

The aim of this project is to examine the reliability, validity and sensitivity of the current physical fitness testing battery at Hibernian Football Club's academy across an appropriate age range (U13 – U18s). By ensuring these tests are both valid and reliable it allows the football club to keep using these fitness tests with confidence and ensures that meaningful conclusions can be drawn from the test results.

Who are the researchers?

The main researcher is Kieran Duffie. Kieran is an Masters by Research student at Edinburgh Napier University and is currently employed as an Academy Physical Performance Coach at Hibernian Football Club as part of this role. A team of researchers; Dr James Dugdale along with Dr David Muggeridge and Professor Russel Martindale of Edinburgh Napier University will be supporting this project.

What will I be expected to do?

You will be expected to carry out the physical fitness testing protocol as normal within the academy in season schedule. However, as part of this study involves a re-test session, you will be required to complete the re-test of the same physical fitness tests after a 5-14 day period following the first testing session. The testing sessions will be carried out on your normal academy training nights and will take place at the Hibernian Training Centre.

Inclusion Criteria

Male participants between the ages of 11-18.

Currently playing for Hibernian FC academy at either U13,14,15,16 or 18 level.

Currently injury free and free of injury for 3 months prior.

Exclusion Criteria

Male or female playing full time football (i.e. development squad)

Male or female playing academy football out with Hibernian FC

Muscular injury within 3 months prior

Illness within 2 months prior

Previous muscular or skeletal injury effecting any of the testing battery (i.e. plyometric/power output)

What are the potential risks to me of taking part?

The risks associated with participation in this testing session are no different to the risks associated to the regular testing battery that is currently carried out within the football club. Mitigating circumstances will be put in place to negate any risks. All responses are completely anonymous to ensure you can respond freely to all questions.

Do I have to take part?

Your involvement in this research is completely voluntary. As noted, the first testing session is part of Hibernian FC academy physical fitness testing schedule, therefore this session will be mandatory. However, the re-test session is completely voluntary and as a volunteer you do not have to participate or continue with the study if you do not want to. If you decide you do not want to continue with the study, then you do not need to provide a reason for your decision. Please note that due to the strict confidentiality process submitted data cannot be withdrawn as we cannot match data to individual participants. Therefore, withdrawal from the study will be possible up until the data has been anonymised. Following the data being anonymised, withdrawal will no longer be possible.

What will happen to the information collected?

The information you provide will be treated confidentially and through the online platform no data can be traced back to any individual participant. All information collected will be stored securely on the encrypted Edinburgh Napier University drive with a back-up on a secure encrypted external hard drive that will be locked in a storage draw. The back-up data will be deleted at the end of the project. Data on the secure drive will be kept for 10 years before being deleted in line with GDPR data collection policies.

What happens next?

After reading this information form and discussing any questions with Kieran, if you are clear about the process involved and would like to participate, please complete the consent process.

If, after reading this information form you do not want to participate you do not need to do anything else. Thank you for your time.

If you have any questions, please contact Kieran Duffie via email at

[redacted]

Appendix 2) Participant and Parent/Guardian Consent Form

Declaration of Informed Consent

The aim of this project is to examine the reliability and validity of the current fitness testing battery at Hibernian Football Club academy. This will follow a test re-test protocol with the re-test session taking place between 5-14 days after the first testing session. Data collection will include all tests from the current testing battery carried out by the Hibernian FC including the Countermovement Jump, Drop Jump, Isometric Hamstring Strength, Flying 20m Sprint and 1000m Time Trial.

1. I have been informed that the general purpose of this study is to examine the reliability and validity of the current fitness testing battery at Hibernian Football Club academy

2. I have been informed that participation in this study will involve carrying out multiple physical performance tests within Hibernian FC current fitness testing protocol.

3. I give permission for the researcher to use the testing data from the test re-test protocol being carried out as well as previous & future testing data collected during scheduled academy testing sessions as part of the research project.

4. I have been informed that the whole process is completely confidential and there is no way for the researchers to access who provided specific data.

5. I have been informed that there is no anticipated discomfort as a part of this study.

6. I have been informed that the researchers will gladly answer any questions regarding the procedures in this study at any stage.

7. I have been informed that withdrawal from the study is possible up until the data collected has been anonymised. There will be a 14-day washout period after data collection in which participants will be able to withdraw their participation and data from the research project. Once the data analyses has begun and data has been anonymised, participants will no longer be able to withdraw their data from the project. I have been informed that due to strict anonymity process submitted data cannot be removed.

8. I understand that if I have any concerns about this project I can contact Kieran Duffie [redacted] or Dr James Dugdale [redacted]

9. I acknowledge I have received a copy of this form, an information sheet and that I have read and understand the above instructions regarding my participation in this study.

Name of Participant: _______________

Signature of Parent/Guardian: ________________ Date: ____________

Signature of Participant: ________________

Appendix 3) Key Stakeholders Focus Group Consent Form

Declaration of Informed Consent

The aim of this phase of the project is to establish the rationale for the current testing battery via a qualitative approach of a focus group including the key stakeholders (coaches, performance managers and practitioners) within the club's academy structure.

1. I have been informed that the general purpose of this phase of the study is to establish the rationale for the current testing battery carried out within the club's academy for age groups u13 – u18.

2. I have been informed that my participation in this study will involve taking part in a focus group interview to discuss the rationale for the current testing battery within the club's academy.

3. I have been informed that the focus group interview will be recorded by the researcher and they will be decrypted with data being used as part of the research study. I therefore agree to the focus group discussion being audio recorded and used for data analysis.

4. I have been informed that there is no anticipated discomfort as a part of this study.

5. I have been informed that the researchers will gladly answer any questions regarding the procedures in this study at any stage.

6. I have been informed that I am free to withdraw from the study up until the focus group discussion has finished if I desire. However, once the focus group is finished participants will no longer be able to withdraw from the research project. Once the focus group has finished, data will no longer be able to be withdrawn as the audio recording is a constitutive part of the collective discussion among the researcher and participants. I have been informed that due to strict anonymity process submitted data cannot be removed once it has been anonymised.

7. I understand that if I have any concerns about this project I can contact Kieran Duffie [redacted] or Dr James Dugdale [redacted]

8. I acknowledge I have received a copy of this form, an information sheet and that I have read and understand the above instructions regarding my participation in this study.

Name of Participant: _______________ Signature of Participant______________

Date: __________

Appendix 4) Physical Performance Coaches Focus Group Questionnaire

Main Question	Prompts	Probes
Could you briefly summarise your role as a practitioner?	What do you want to achieve with the players? Describe how complex your role is?	How do you go about achieving this? What are the barriers?
How do you view your role in relation to player development?	What different elements need to be considered when developing players? What do you find important in regard to developing a player physically?	Barriers to this? Why?
Tell us about your KPI's in regards to physical testing?	Do you set out Key Performance Indicators for different age groups?	Does this change for certain age groups? What KPI's?
Where does the decision to include the current physical fitness tests come from? What's the rationale?	Is there a reason for excluding certain other tests? Same amount of emphasis on each test? If not why and which ones? How about the reliability of the tests?	Previous experience and knowledge influence this? Has this been determined through previous reliability testing / previous studies?
How do you use this testing data you gather?	Talent identification – Short vs Long term? Future potential? How much does testing influence programming for players? Do you consider maturation when you analyse or interpret the data?	Why these tests? Why not others? S&C programming and training plans?

How coherent is it between coaches and sports science in regard to the use and interpretation of fitness testing data?	How is the communication between the two? Is there an agreement on how data/profiling from the testing is used?	What could be improved?
In what ways could fitness testing, its use and application be improved?	How is it carried out / used / interpreted? Is the time-consuming part a factor for testing? Is this a Rational for these easy quick key indicators?	Anything else you would include if you had the technology or time/resources?

Appendix 5) Technical Coaches Focus Group Questionnaire

(a) Main Question	Prompts	Probes
Could you briefly summarise your role as a coach?	What do you want to achieve with the players? Describe how complex your role is?	How do you go about achieving this? What are the barriers?
How do you view your role in relation to player development?	How does this fit in with winning? Prioritise player development over team results and does this change with age groups? What different elements need to be considered when developing players? What do you find important in regard to developing a player physically?	Do you feel winning/development conflicts at all? Barriers to this? Importance of each element
How do you make your decisions in regard to players future potential or progression through the academy?	Do you look for certain attributes or characteristics? Does this change depending on age group? What about the physical testing? Do you set out Key Performance Indicators for players?	Why these characteristics? Why not others? Which age group and why? Does this play a part? More important for certain age groups? Do any of these KPI's include testing data from the physical fitness testing? What physical testing? If none, why?

You know we test the players regularly throughout the season using physical fitness testing. How do you use this testing data?	Talent identification? Future potential? Is there any particular tests you look out for? (Flying 20m Sprint, 1000m TT etc?) Are there any tests you do not find very useful or do not understand how it correlates to the players in a game/training? Do you take into consideration G&M when assessing players testing results?	Why these tests? Why not others? Why? History of using different testing battery previously? What would help coaches in this aspect? Full understanding of G&M and how this effects players physical outputs going through PHV?
How coherent is it between coaches and sports science in regard to the use and interpretation of fitness testing data?	How is the communication between the two? Is there an agreement on how data/profiling from the testing is used?	What could be improved?
In what ways could fitness testing, its use and application be improved?	How it is carried out / used / interpreted? Time consuming? Is this a Rational for these easy quick key indicators? Anything else you would include if you had the tech or time or resources?	

Appendix 6) Exemplar working of six-stage process of Focus Group analysis (stage 2 – coding)

Limited time of contact with each age group.
One-to-one coaching time is limited due to time & also player-to-coach ratio
Educate parents on benefits of different sports / movement skills for long-term athletic development
Managing player's load in relation to their maturation stage (i.e. inc growth rate).
Allows Sports Science/coaching staff to reduce player's weekly load and substituting this with altervative training such as stability or mobility work.
Establishing the fundamental movement patterns like hinge, brace, push, pull.
Build capacities within these movements such as Strength & Power
Developing each team at an age specific rate
Clear path of physical progression from u13 all the way to Development/First team
Latter stages of academy introducen individual development plans.
Ensuring younger academy player's are involved in greater range of sports - not early specialization
For example there is a progressive year to year improvement in development of the players. < Greater chance of graduating through academy to first team
To gauge how well the S&C programming is working to show players are progressing physcially within season and also year to year
Provide more individualised S&C as players move into later stages of academy. Focus os individual MAS prescritpion for runs etc.
Specific to each age group on how well/poorly their phyiscal profie is for each player
Allows sports science department to plan and periodise for each squad to work on weaker pillars within the testing (i.e. Explosive & Braking Strength)
Data has to be presented in a way in which it isn't just used as a confirmation tool for coaches but as a fresh insight which is what we actively seek to to when presenting the information
Can be collaborative when its data & feedback about squads/individuals that allow coaches to implement sessions to improve highlighted weaknesses on pitch.
Reports sent out to coaches through detailed and descriptive email of the physical fitness testing highlighting strengths/weaknesses of squads as whole and individual player basis.
Reports provide clear image of where each sqaud/player fits into the quadrants within each physical pillar.
Coaches sometimes question why the physical profiling data doesnt match what they are seeing in training/games.
Coaches want something objective to justify their decisions when speaking to parents
Our job as sports science to make the reports clear, easy to read and explain as it is coaches who are having the difficult conversations with parents.
Testing has big influence for programming as it allows reports to show squad and individuals overall profile and where they sit in relation to the quadrants within the physical pillars.
Sports office is used to log maturation data which produces reports for each squad.
Key indicator is which stage of percentage of adult height player's are at - pre/circa/post PHV
Players in circa category can be flagged in reports to make coaches/medical staff aware player's are going through their peak hieght growth and may be more susceptible to growth related injury's
Having a more in-depth conversation with coaches to ensure full understanding of maturation report and what each stage of maturation means for the players
To show special physical profile players - players who are genetically good athletes and not just those that are early developers compared to their peers in squad
Allows feedback to coaches to see both the squads as a whole and individual players to who are performing well or not performing well physically
In-house physical profile of different test with benchmarks for each test based off historical internal data over a few years
Testing battery based off out-sourced physical profile framework from English FA, which has been adapted.
Got to be pragmatic and realise what is feasable and what you can logistically do
Previous (pre-covid) testing was two week protocol as it took two hours, which wasn't popular with coaches as it took more time away from football.
We now use proxy measures of speed,agility,decelleration ability that are quicker and more pragmatic which are used to give us a feel of speed/agility/decelleration
We now test the whole squad in 45 minutes being much more pragmatic and getting good data
Advancement of technology means we no longer need 2/3 practitioners to complete tests now 1 practitoner can carry out testing using force decks etc
There is legitimate scientific rationale to use these tests, and when you commit to it its smart to stick with it as the bigger your data set becomes the more insight you get
Not perfect, but overall a pretty solid protocol.
Utilise an agility/COD test for the goalkeepers. Measure speed directly if time wasn't an issue. Possibly testing isometric strength and repeated sprint ability which are interesting areas imo.
Coaches familiar with testing and how this translates to pitch. Have chats with coaches after reports have been distributed to discuss players on an individual basis
Investment from club in new technology such as Force-Decks, Force-Frame & Nordbord from VALDHub
To show that the investment from the club in academy sports science through new technology is worthwhile
Potential to detect prospects for the future if certain players who have not started their peak height growth but are still performing very well physically within the profiling categories and squad